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ABSTRACT

Two fifth grade measures of the ability to deal with symbolic relationships were developed for use in future factor analytic research concerning the nature of intelligence. Circle Reasoning was adopted from an adult level test by modifying the number of symbols and the nature of the principles on which the items were based. Item analysis results suggested that the four major categories of relationships formed a continuum of difficulty according to the complexity of symbolic relations. Evidence of a learning set effect provided questions for future research. A Number Series-Correction test proved too difficult for fifth grade subjects. A Number Series-Completion test was somewhat easy. Complexity of relations and degree of deviation from the examples were the factors concluded to account for the range of item difficulties. A correlation between Circle Reasoning and Number Series-Completion of .58, corrected for attenuation, suggests that the underlying abilities may be common to both tests as has been claimed in similar research with older subjects. (Author)

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Report from A Structure of Concept Attainment
Abilities Project

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Technical Report No. 135

TWO FIFTH GRADE MEASURES OF COGNITIVE ABILITIES

**Report from A Structure of Concept Attainment
Abilities Project**

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June, 1970

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STATEMENT OF FOCUS

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical Report is from the Structure of Concept Attainment Abilities in Program 1. The general objectives of this project are to identify basic concepts in language arts, mathematics, science, and social studies appropriate at a given grade level; to develop tests to measure achievement of these concepts; and to develop and identify reference tests for cognitive abilities. These will be used to study the relationships among learned concepts in various subject matter areas, cognitive abilities, and possibly, certain cognitive styles. The results of this will be a formulation of a model or structure of abilities in concept attainment.

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TABLE OF CONTENTS

	page
ACKNOWLEDGMENTS	iv
LIST OF TABLES AND FIGURES	vii
ABSTRACT	
I INTRODUCTION	1
II RELEVANT RESEARCH.	8
III METHOD	19
Purpose.	19
Subjects	19
Examiners.	20
Procedure.	20
Analysis	21
IV CIRCLE REASONING: DEVELOPMENT AND EVALUATION.	26
V NUMBER SERIES: DEVELOPMENT AND EVALUATION	41
VI CORRELATION.	52
VII DISCUSSION AND CONCLUSION.	54
REFERENCES	57
APPENDICES	60

LIST OF TABLES AND FIGURES

Table		page
1	Principles: Circle Reasoning from the Aptitudes Research Project.	10
2	Principles: Preliminary Circle Reasoning Test. .	28
3	Principles: Circle Reasoning, Forms A and B. . .	30
4	GITAP Summary: Circle Reasoning, Form B.	36
5	Principles: Number Series, Forms A and B	43
6	Selected NS-B Items	45
7	GITAP Summary: Number Series, Form B	50

Figure		page
1	Guilford's Structure of Intellect model.	6
2	A Typical Item Characteristic Curve.	24

Chapter I

INTRODUCTION

The nature of intelligence has long been questioned, but the specific component germane to this study, the ability to deal with symbolic relationships, has gradually been recognized as an important element of intelligence. During the course of the mental testing movement many different theories of the nature of intelligence have evolved. As these theories have changed, so have the methods of measurement.

Until the turn of the century most mental tests emphasized sensory and motor tasks. Researchers such as Sir Francis Galton and James McKeen Cattell believed that such tests offered precise and accurate measurements that would provide an indirect indication of the complex intellectual functions that they believed were too difficult to measure objectively. Alfred Binet, too, experimented with psychomotor tests, but he preferred to include, even if less precisely measured, such complex functions as imagination, comprehension and reasoning. These aspects of intelligence in addition to sensory and motor performances were included in the 1905 Binet-Simon Scale and its revisions. (Anastasi, 1968)

Until World War I most mental tests were individual ones. American involvement in the war, however, prompted the development of

group intelligence tests for classification of personnel. The Army Alpha was designed for general routine testing, and the Army Beta was a nonverbal scale used primarily with illiterates. These tests and their revisions served as models for the many group tests that were developed in the subsequent boom of mental testing. Before long a desire for intraindividual comparisons developed, which created the need for tests designed to reveal differences in various functions. The means for constructing such tests were gradually provided by the study of the organization of traits.

Charles Spearman (1904, 1927), the British psychologist, provided the first theory of trait organization based on a statistical analysis (factor analysis) of test scores. Until that time the material and phenomena that he studied had been considered too complex to analyze. In addition to isolating and describing factors, he theorized about the nature and structure of intelligence. According to his two-factor theory, every cognitive task is a function of a large general factor (g) and another factor (s) specific to that particular task. Every task has its own ratio of general intelligence to a specific factor. Spearman was careful to distinguish his theory from a monarchic one, which would imply that general intelligence is equally important in every cognitive task. Eventually he also admitted the existence of group factors which are common to some activities but not to all.

Spearman maintained that since the general factor is common to all abilities, it is the best predictor of a person's performance

from one situation to another. According to Anastasi (1968), Spearman proposed that a single test highly saturated with "g" should be substituted for the heterogeneous collection of items found in intelligence tests at that time. For this purpose he suggested tests dealing with abstract relations as the best measures of "g."

Spearman felt that the common theme represented by "g" could be described as the ability to "educe relationships." Relations are perceived connections between things. In Spearman's terms, the presentation of any two or more characters ("fundaments") "tends to evoke immediately a knowing of the relation between them" (1923, p. 63) and "the presenting of any character together with any relation tends to evoke immediately a knowing of the correlative character" (1923, p. 91). An application of these principles is demonstrated by an analogy problem. Given two fundaments, one must educe the relation and then use that relation with a third fundament to educe a fourth fundament. A more complicated example of the principle is involved in the types of problems developed in this study in which one must educe a relation or group of relations that concern several given fundaments and then educe another fundament.

Spearman's psychological interpretation of the "g" factor as mental energy that causes intellectual performance was challenged by E. L. Thorndike (1927). Thorndike believed that connections (bonds) between stimuli and responses underlie intelligence. According to Thorndike, intelligence is quantitative rather than qualitative.

People respond differentially to the myriad of elements of ability, which may be sampled by tests. These tests are correlated when they sample overlapping elements. If the intercorrelations of several tests have the formal properties necessary for Spearman's "g", they can also be explained by multiple bonds or overlapping elements. (Humphreys, 1968) Thus Thorndike viewed "general intelligence" as merely a term for classifying a large number of innate abilities to become intelligent. These innate abilities fall into three main categories: social intelligence, motor intelligence and the intelligence for words and abstract ideas. He believed these three types of intelligence to be related, but not necessarily to a high degree. (Colvin, 1922)

Somewhere between Spearman's unitary-trait theory and Thorndike's atomistic view, and influenced by both, lies the group-factor approach to intelligence, one of the leading exponents of which was L. L. Thurstone. According to Thurstone's theory, certain mental abilities have a primary factor in common which distinguishes them from other groups of mental abilities. Each group has a different primary factor in common. Originally Thurstone believed that the primary factors were for the most part independent of each other, but later research showed that the primary abilities are positively correlated. Thurstone explained this relationship in terms of a "second-order factor." (T.G. Thurstone, 1962)

After many factor analyses of various tests from grade eight through college level, The Chicago Tests of Primary Mental Abilities (PMA)

was first published in 1941. A reasoning (Induction) factor, which is of interest to the present study, was found in Thurstone's 1938 factor study and has subsequently been included as one of the PMA subtests in grades 4-12. The particular test items designed to measure this ability vary for different age levels.

J. P. Guilford has also been interested in the factor analytic approach to identifying cognitive factors, but his theory and technique of mapping them differ from Thurstone's. Thurstone was willing to accept correlated, hierarchically organized factors, but Guilford does not. Guilford developed a model of the structure of intellect (SI) that includes all types of mental or information-processing activities as distinct factors in a three dimensional cross-classification system. (See Figure 1.) This system emphasizes the difference between test content and test process, where Thurstone's explorations mixed processes, such as reasoning, with content factors, such as numbers. (Guilford, 1967)

Each of the three current dimensions (a fourth--"modality"--may be added) in the SI model is divided into a set of mutually exclusive categories that are supposed to apply uniformly throughout the classification. Each cross-classification represents an independent factor of intelligence which can be described by the code letters for that particular intersection. The ability to recognize principles in sets of symbols falls into Guilford's CSS factor: the Cognition of Symbolic Systems. Guilford (1967) states that Thurstone's induction factor is in part the CSS ability.

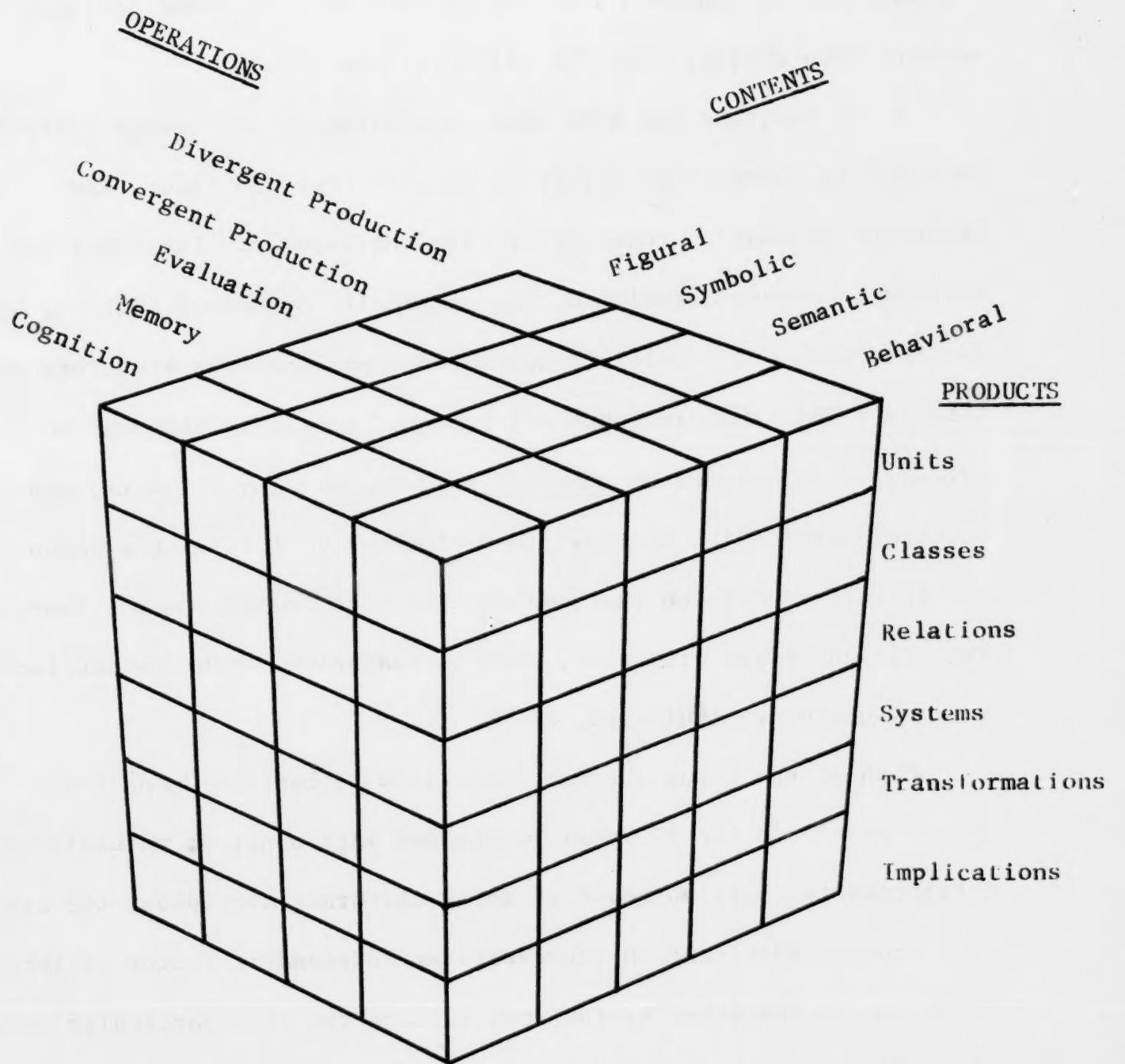


Fig. 1 Guilford's Structure of Intellect model. (1967)

In summary, there have been many different theories of the nature of intelligence that have been popular over the past century. The continuum has ranged from Spearman's general factor to Guilford's projected 120 or more unique factors. Of particular importance to this study is the fact that some sort of reasoning or Induction factor (Thurstone), Education of Relations (Spearman), intelligence for abstract ideas (Thorndike), or the ability to deal with symbolic relationships (Guilford) has been included in several major approaches to the nature of intellect in this century. Improved methods of factor analysis are currently providing new strategies for isolating and describing cognitive abilities.

The purpose of the present research was the development of two measures of cognitive abilities to be used in future studies concerning the nature of intelligence. The two tests chosen for investigation in this study were suggested by Guilford's CSS factor studies and by reasoning subtests in several well-known test batteries. The intent of the study was to develop a number series test and a circle reasoning test which would be appropriate for the population of school children during the summer after fifth grade in suburban Wisconsin public schools.

Chapter II

RELEVANT RESEARCH

The two tests developed in this study, Number Series and Circle Reasoning, are both primarily characterized by a task that requires the subject to find a rule or principle for each item in the test. "Principle" may be thought of as the relationship that connects two or more symbols. The ability to discover principles has been called "Induction" by Thurstone, the "eduction of relations" by Spearman, and the "eduction of patterns" (EP) or the "cognition of symbolic systems" (CSS) by Guilford.

The circle reasoning (CR) test developed in this study is related to several tests used by Thurstone in his 1938 factor analytic study with college subjects. Among these are Figure Classification and Pattern Analogies, which both loaded on his Induction factor. They require that the subject find a principle relating two or more symbols and then demonstrate that he knows the rule by applying it to other symbols.

Thurstone (1940) included a new test called "Marks" in a factor analytic investigation with high school age subjects. Thurstone reported that Marks loaded only on the Induction factor. No reliability estimates or test description were reported in that study. In 1941, Thurstone's associate, Robert Blakey, (Brown and Blakey) adapted and

simplified the Marks test for inclusion in a non-verbal reasoning test for high school students. This modification was the first "Circle Reasoning Test." Blakey's test consists of fifteen items, each comprised of five rows of circles and dashes. One circle in each row has been darkened according to a rule. The task is to discover the rule from the four exemplars given and then to apply the rule to the fifth row. No list of rules was available. Blakey's test was somewhat easy (mean was 10.8 out of 15). His reliability, determined by the odd-even method and corrected for double length with the Spearman-Brown formula, was quite high (.94) for a relatively short test. In a factor analysis (Blakey, 1941) of the entire high school level non-verbal reasoning test developed by Brown and Blakey (1941), Circle Reasoning loaded on the Inductive Reasoning factor, which supported Thurstone's results with Marks. Since Circle Reasoning had proven to be such a good measure of Inductive Reasoning, Green, Guilford, Christensen and Comrey (1953) included it in a factor analytic study in the Aptitudes Research Project at the University of Southern California. The types of rules used varied from those that were dependent on the ordinal position of the circle (fifth circle in the row is dark) to rules in which the position of the circle is related to the position and/or number of dashes or other circles (third circle after a dash; middle circle in a group of three circles). The rules used were rather complex considering that there were fifteen symbols in a row. (See Table 1 for a complete list of the principles used by

TABLE 1

Principles: Circle Reasoning from the Aptitudes Research Project

I. Relative to other circles only

(Ordinal position in a row - stationary)
5th circle in a row (from left)

II. Relative to circles and dashes

1st circle after 2 dashes
1st circle separated from other circles by dashes ("alone")
1st circle to the left of the 2nd dash

III. Relative to groups of circles (groups defined by dashes)

1st circle in a group of three circles
2nd circle in a group of two circles
2nd circle in a group of five circles
3rd circle in a group of five circles
last circle in the largest group of circles

IV. Relative to circles and rows

1st circle in a group of N (N = the number of the row)
5th circle (marked circle moves right one place each row)
6th circle (marked circle moves right one place each row)

V. Relative to circles and dashes

1st circle after 2 dashes and 2 consecutive circles

Guilford and his colleagues at the Aptitudes Research Project.) An informal experiment with a modified version suggested that the novelty of the task tends to disappear somewhat after several problems have been solved. Hence it would appear that if the test were not speeded, adult subjects would have a good chance of eventually discovering most of the rules. From the time limit imposed in Guilford's studies (8 minutes for 15 items), it would appear that the variance would be a function of the speeding, which may have affected Guilford's reliability.

Green et al. (1953) used Air Force Officer Candidates and Air Cadets as subjects. The fifteen-item test was given with eight minutes working time, which was termed "not highly speeded." The mean and variance were not reported. The Kuder-Richardson 20 (KR 20) formula reliability was estimated as .91, which is rather high. Using two different solutions, Green et al. found that Circle Reasoning loaded on the EP factor (the ability to see complex relationships). Subsequently, Guilford and his colleagues used the test as a reference test for the EP factor in other studies.

Guilford, Kettner and Christensen (1955) also found that Circle Reasoning loaded on the EP factor. In this study the reported mean was 9.29 (out of 15), with a standard deviation of 2.31. Hence this study obtained a slightly high mean, as had Blakey (Brown and Blakey, 1941). The .62 KR 20 reliability estimated by Guilford et al. (1955) was much lower than that of Green et al. (1953).

In 1956, Guilford, Kettner and Christensen again found that CR loaded on the EP factor. They concluded that the existence of the EP factor had been strongly supported by this and the previous studies. The mean for this test was not as high as previous studies even though the time limit was the same, and the sample items appeared similar to those in earlier work. The mean was 7.6, just about half of the possible. The standard deviation was 2.67. The KR 20 reliability was reported as .62 "from a previous study." One might wonder why there had been a drop from .91 to .62 and why this lower reliability was retained in following studies. Similar results were also reported by Kettner, Guilford and Christensen in 1959.

In 1960, Guilford, Merrifield, Christensen and Frick again reported the CR reliability (KR 20) as .62 "from a previous study." The mean was 7.46, and the standard deviation was 2.67, which are similar to Guilford's 1956 results. At this stage the EP factor on which CR loaded was renamed the Cognition of Symbolic Systems (CSS) as part of the SI model. (See Figure 1.)

The first set of questions proposed for this study, the results of which should prove helpful in future factor analytic research, was: can the complex rules and the format used by Blakey, Guilford and others with adult male subjects be modified and incorporated into a more highly reliable unspeeded test that is appropriate for both male and female subjects at the fifth grade level? If such a test can be developed, what will the item analyses suggest about the appropriateness of particular kinds of rules to this age level?

The Number Series (NS) type of inductive reasoning test has been used much more commonly than the Circle Reasoning test. Several different formats are in use. For a given format, the complexity of the "rules" or "principles" (relationships on which the series are based) may cover a wide range of difficulty.

Thurstone (1938) included an NS test in his investigation of the primary mental abilities in college age subjects. Each series consisted of five numbers and two blanks. The task was to discover the rule and fill in the blanks with the correct answer, in a free answer format. The rules were based on addition, subtraction, multiplication, division and combinations of these. Thurstone's test loaded on his Induction factor. A reliability of .80 was estimated by the tetrachoric correlations of odd and even items.

Guilford and his associates have used two different types of NS tests in their investigations of the EP or CSS factor with adult male subjects. Both kinds of tests have loaded on CSS and several other factors. Guilford (1956) used a number series test in which the task was merely to describe the rule that fits a given series. (No application of the rule was necessary.) There were no remarks about the rules used. The test loaded on four factors: EP, General Reasoning, Symbol Manipulation and Symbol Substitution. The alternate form reliability was sufficiently high (.86). These results were confirmed by Kettner et al. (1959).

At this point an attempt was made at the Aptitudes Research Project to find an NS test that was factorally less complex than those used in previous studies. Guilford et al. (1960) included a test in

which the task was to find and mark the number in the series of five or six numbers that did not follow the rule for the entire series (16) (e.g., 2 4 8 16 32 64 OK). This task, Number Series Correction, proved complex also. It loaded on three factors: CSS, Cognition of Symbolic Classes, and General Reasoning (Cognition of Semantic Systems (CMS)). It was suggested that subjects probably verbalize the rules even when not asked to describe it, which may in turn lead to confusion with semantic tasks. If this is true, one might wonder why the Circle Reasoning test has not also loaded on CMS.

The alternate form reliability of the Number Series Correction test was not particularly high (.55). The mean was 8.94 out of 20 items with a standard deviation of 3.36; hence the test was slightly difficult.

Two different types of NS tests developed by Sister Canisia (1962) were used as reference tests for a reasoning factor with female Ss in a private high school. No specific information was reported about the types of rules used, but the tests were "patterned after number series type tests used by other investigators." One test was in free-answer format; the subject was asked to supply the next number for each series, which is similar to Thurstone's (1938) NS test. There were twenty items for ten minutes' working time. The mean was rather high (16.98 out of 20) with a standard deviation of 3.06. A reliability of .81 was reported, which would appear sufficiently high; however, the type of reliability was not indicated.

The second test developed by Sister Canisia (1962) also used a free-answer format. For this test the task was to indicate the number that does not belong in the series, which was similar to the NS-correction used by Guilford et al. (1960). The rules were for the most part simple addition and subtraction. There were again twenty items, but the subjects were allowed 15 minutes working time. The mean was lower for this test, however, (13.07 out of 20) with a standard deviation of 3.13. The (unspecified) reliability was also lower than the first test but adequate (.71).

Thurstone (1938) refers to the possibility that the same test may be indicative of one or more factors at an early age but of different factors at a later age. This opinion suggests that the isolation of mental abilities should be carried out for each age level separately, and it would discourage the factorial interpretation of a test for widely different age levels. As a consequence, the above research with adult and high school age subjects is helpful in its indications, but studies employing NS tests for symbolic reasoning at an elementary age level are of primary importance.

The attempt to use number series items to measure reasoning abilities in the elementary grade levels of the Tests of Educational Ability (TEA), (Thurstone & Thurstone, 1958) was unsuccessful. In an exploratory study during the development of the TEA battery for grades 4-6, NS items were constructed similar to those used in the TEA for grades 6-9 and 9-12. The task at the higher grade levels involved selection of the appropriate alternative for a blank after 7 numbers in a series. The distributions, even with very simple tests, tended to be bi-modal, and the test

administrators reported that many pupils were unable to comprehend the nature of the task. The TEA technical supplement (Thurstone and Thurstone, 1958, p. 25) states, "We have concluded that for many youngsters the ability to understand these types of problems develops at the fifth or sixth grade level." A review of the NS items from the 6-9 level of the TEA reveals that the rules used are rather complex, and one might wonder how these were adapted for the 4-6 level experimental study. All the rules involve either sequential addition (e.g., $+3+4+5+5+6\dots$) or combinations of operations ($\cdot 2-5\cdot 2-5\dots$). The difficulty of the rules might well have been the crucial factor in the unsuccessful attempt to adapt this test to the 4-6 level.

Thurstone's PMA battery (1962) uses NS items in the Reasoning section only in the upper grade levels. In the fourth through sixth grades, word grouping and figure grouping tests are used to measure Reasoning, while some NS items are used as a measure of the Number Facility (the ability to handle quantitative problems rapidly). The Number Facility series consist of five numbers and one blank, the task being to discover the rule and choose the correct answer from four choices. This test's format is very similar to Thurstone's NS test with college subjects in 1938, but the rules used are quite simple, (all are addition and/or subtraction of constants (e.g., $+5+5+5+5\dots$, $-2-2-2-2\dots$)). Ten such NS items and ten word arithmetic problems are given with only ten minutes' working time. It would appear that the simplicity of the rules and the short time limit for this age level are basic to Number Facility. Consequently, an unspeeded test using a variety of rule complexity would seem appropriate for

measuring symbolic reasoning.

The Lorge-Thorndike Intelligence Tests, Non-verbal Battery (1964), designed to deal with symbolic relationships, has successfully included twenty-five NS items in one of the fifth grade level tests. The manual claims that the tests are primarily power tests and that the time limits (25 items - 9 minutes) were chosen so that very few pupils would make a higher score if they had more time.

The series consist of three to seven numbers. The task is to find the rule and to choose the next number in the series from five choices given. The rules vary from simple addition of constants (e.g., $+4+4+4 \dots$) to sequential operations (e.g., $+1+2+3 \dots$) and alternating operations (e.g., $+2-5+2-5 \dots$). There are also some rules not used in the previously mentioned batteries that are most easily described as based on the "form" or appearance of the numbers (e.g., 806 617 826 637 ____, which is -189, +209, -189, +209, or 7774 7747 7477 ____, which is -27, -270, -2700.)

The Fifth Mental Measurements Yearbook (Milholland, 1959) reports the alternate form correlation for the 1957 scales lies between .76 and .85. The corrected odd-even reliabilities are generally greater than .90.

In summary, three different formats and several different types of rules have been used. The three major batteries mentioned above have reported different results concerning attempts to include number series as tests of symbolic reasoning. The second set of questions posed for this study was: can a reliable unspeeeded number series test be developed (with emphasis on reasoning

rather than number facility) that is appropriate for male and female subjects at the fifth grade level? If such a test can be constructed, what information will it provide about the specific kinds of rules that may be appropriate for this age level?

If reliable tests of number series and circle reasoning can be developed for fifth grade subjects, the question of a correlation between the tests presents itself. In 1938, Thurstone found a correlation of .52 between his Figure Classification test (somewhat similar to Circle Reasoning) and his Number Series test with college subjects. In 1940, Thurstone found that Marks (quite similar to Circle Reasoning) and Number Series correlated .31 with high school subjects. Guilford et al. (1956), using adult male subjects found a correlation of .23 for Circle Reasoning and Number Series (task was to describe rule). Corrected for attenuation, this correlation would be .32. In 1960, Guilford et al. found a correlation of .26 for Circle Reasoning and Number Series-Correction. The corrected correlation is .45.

The evidence that Circle Reasoning and Number Series may involve a common ability with adult subjects does not necessarily mean the same is true at the fifth grade level. A third set of questions was to be considered in the present study: what is the degree of correlation between Circle Reasoning and Number Series at the fifth grade level, and does this correlation support the implications of the item analyses about the types of rules that are appropriate? If the two tests are positively correlated, one might expect that difficult rules in one test may be similar to the difficult rules in the second test.

Chapter III

METHOD

Purpose

The purpose of this study was to develop two tests, Number Series and Circle Reasoning, as suggested by Guilford's Cognition of Symbolic Systems factor (Guilford, 1967). The population of interest consisted of both male and female subjects during the summer after fifth grade in Wisconsin suburban public schools.

It should be noted that while the tests are intended for future use in factor analytic studies of the nature of intelligence, the tests as developed in this study are still in an experimental stage and require proper norming, reliability and validity studies before more general use should be made of them.

Subjects

The subjects (Ss) selected for this study attended fifth grade classes in five suburban public schools located in West Allis and Sussex, Wisconsin. The total number of Ss tested was 317. The number of Ss taking a particular test varied from 133 to 137. Eighty-seven Ss took the revised forms of both Circle Reasoning and Number Series, for which a correlation coefficient was calculated. Subjects who were absent were not tested. All the teachers were very cooperative, and the majority of the pupils appeared interested and well motivated.

Examiners

The three test examiners (Es) included the author and two other experienced test administrators. All Es were carefully acquainted with the purpose of the testing, the content of the tests and the test manual. Group decisions were made prior to testing in regard to the type and extent of individual help to be given. (See Appendix A.)

Procedure

On January 14, 1970, Form A of the Circle Reasoning (CR-A) was administered to 136 fifth graders in five classes in West Allis, Wisconsin. Form A of the Number Series (NS-A) was administered to 137 Ss, the same classes that took CR-A. On January 27 and January 28 in Sussex, Wisconsin, the revised Circle Reasoning test (CR-B) and the revised Number Series test (NS-B) were administered to 134 and 133 fifth graders respectively. Eighty-seven of these Ss took both tests. Testing involved only one hour of class time per day per pupil. Half of this time was allotted to either Circle Reasoning or Number Series and the other half to unrelated verbal or memory tests. Possible order-of-testing and time-of-day effects were balanced.

The testing situation remained standard for all groups of Ss. Examiners read the directions aloud while the pupils followed in their test booklets. Examples were worked on the blackboard in front of the class, and all pertinent questions were answered. Es emphasized that many different kinds of patterns would be included in the test. Subjects were allowed 20 minutes' working time, which proved sufficient for most Ss to finish without haste. All teachers remained in the classrooms for the major portion of the sessions to maintain order and serve as proctors if needed.

Analysis

The GITAP program (Baker, 1968) was used to analyze the field test results of CR-A, CR-B, NS-A and NS-B. The information provided by this program served as a basis for decisions concerning format, directions and item content.

Several descriptive statistics for the test are provided in the GITAP printout. Among these are the individual scores obtained by each S , the mean ($\bar{X}$), standard deviation (s), Hoyt ANOVA reliability, and the standard error of measurement (Se).

In order to maximally discriminate among subjects it was desirable in this study to have a wide range with the mean somewhat near half of the total possible score.

The Hoyt reliability is an internal consistency estimate based on a two-way analysis of variance procedure. It provides estimates equivalent to those obtained with KR 20 or Cronbach's coefficient alpha. A reliability of approximately .80 or higher was considered suitable for this study.

The standard error, a measure of the absolute accuracy of measurement, is related to the reliability: (Magnussen, 1967)

$$Se = s \sqrt{1 - r_{tt}} \quad .$$

The higher the reliability, the smaller the range within which one can estimate a subjects's classical true score with a given degree of probability. Therefore a relatively small Se was desirable.

The GITAP program also provides several item parameters: difficulty level (p), biserial response-criterion correlation (r_{bis}), X50 value and beta (β), for each possible choice. These parameters are discussed in M. L. Harris

(1968), but they will be briefly mentioned here for readers who may be unfamiliar with them.

Item difficulty. A difficulty level is reported for each possible answer and represents the proportion of subjects who selected that particular alternative. Hence, the difficulty level reported for the correct choice of an item indicates the proportion of the sample who answered the item correctly. In this study it was desirable to have a wide range of item difficulty, approximately between .10 and .90, with most items functioning near middle difficulty in order to maximally discriminate among Ss. In other words, it was desirable to have some items that were very easy ($p=.90$), some very hard items ($p=.10$), and several of middle difficulty.

Biserial Correlation. The biserial r is a correlation between a particular choice of an item and some criterion. In this case, the criterion was the total test score. A high positive correlation for the correct choice indicates that the subjects who got the item correct tend to have high total test scores. Highly negative coefficients are desirable for the incorrect choices since that would mean that the subjects who chose the wrong answers tend to have low test scores.

X_{50} values and β . X_{50} and beta are very helpful in visualizing the properties of an item and specifying them mathematically. These two parameters, as explained in Baker (1964), are perhaps more useful than difficulty level and biserial correlation. Difficulty level indicates only the proportion of subjects who chose a particular alternative but does not give any information about who those subjects are. X_{50} and β are based on an item characteristic curve approach to item analysis. An item characteristic curve shows the relationship between ability (for which

a criterion score is often substituted) and the probability of response. The most common form of the item characteristic curve is the normal ogive, which is fitted to the proportion of subjects at each criterion score level who chose the alternative of interest. Thus, there is a curve for every item choice. Two parameters, usually the mean and standard deviation, are required to completely specify the ogive. X_{50} is essentially the mean, and β is the reciprocal of the standard deviation of the ogive.

The X_{50} , then, is the point on the criterion scale, which has a mean of zero and a standard deviation of 1, where a subject would have a fifty percent chance of choosing the response. In the analysis of this study the criterion variable was the total test score. Hence, if X_{50} were +1.0000 for the correct choice of an item, and the test scores had a mean of 10 and standard deviation of 2.0, a subject with a score of 12 would have a fifty percent chance of answering that item correctly. Therefore, this item would be somewhat difficult. One method of maximally discriminating among subjects is to have a range of difficulty level. Thus, a range of X_{50} values between ± 2.0 was appropriate for this study, with most of the items functioning in the middle of the range ($X_{50} = \pm .75$).

Beta is the measure of discrimination that is used in conjunction with X_{50} to properly interpret the items. Beta is technically the reciprocal of the standard deviation of the item characteristic curve, but it may be thought of as the slope of the curve at the X_{50} point. Beta has a range of plus to minus infinity. The larger the β , the more vertical the slope of the curve at that point; hence, the more clearly does the item discriminate. A high positive β for the correct choice of an item indicates that the subjects who chose that alternative had relatively high criterion scores. Since one would hope that performance on each item correlates well with

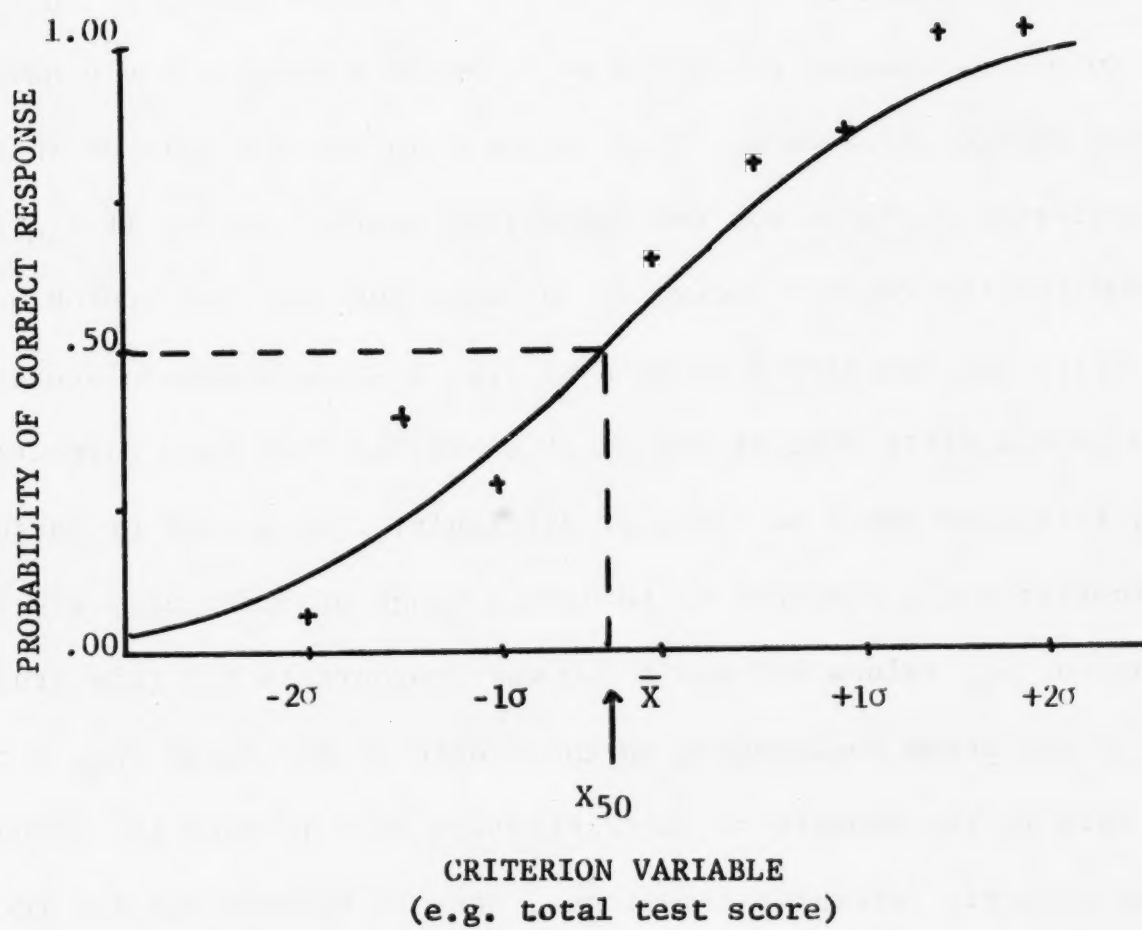


Fig. 2 A typical item characteristic curve. Baker (1965)

performance on the test as a whole, it is desirable that the correct choice have a high positive β and that the incorrect choice have high negative β s. If all subjects with test scores below the X_{50} point get the item wrong, and all those with scores above it get the item right, the β for the correct choice approaches $+\infty$ and the item discriminates perfectly. This would be indicated by 0.0000 in the beta column. The r_{bis} may be greater than 1.0 if there is a bad split in item difficulty. When β is nearly zero (i.e. the item does not discriminate at all) the variance of the ogive is quite large and the curve is stretched out. Total test score is then uncorrelated with success on the item. In this case, β may also appear as 0.0000, but the r_{bis} will be very low, and the X_{50} becomes very unstable and may be very large.

Chapter IV

CIRCLE REASONING: DEVELOPMENT AND EVALUATION

Circle Reasoning-Form A (CR-A) was adapted from the Circle Reasoning test used by Guilford and his associates (Green et al., 1953; Guilford et al., 1955, 1956, 1960; Kettner et al., 1959) in the Aptitudes Research Project as taken from a test developed by Robert Blakey (1941). In the adult-level form, each item is comprised of five rows of circles and dashes. Four rows demonstrate a principle. The subject's task is to discover the principle and apply it to the last row. An example of this type of item follows: (From Guilford, 1967, p. 96)

0	-	●	0	-	0	0	0	0	-	0	0	0	-	0
0	0	-	●	-	0	0	-	0	0	0	-	0	0	0
0	0	-	●	0	0	-	0	-	0	-	0	0	0	0
0	-	●	0	0	-	0	-	0	0	-	0	0	0	0
0	0	0	0	0	-	✕	0	-	0	0	0	-	0	-

As may be seen, the fifteen symbols per row provide the possibility of extremely complex principles. A list of the principles employed in Guilford's test may be found in Table 1.

In the fall of 1969, a thirty-six item preliminary test was written and informally administered to six Educational Psychology graduate students. The items, with ten symbols per row, were based on Guilford's principles. The rules used by Guilford and his colleagues were quite complicated. They included rules in which the dark circle

is related to (A) other circles only (6th circle from left), (B) dashes and circles (1st circle after 2 dashes), (C) groups of circles (2nd circle in a set of 5 consecutive circles; last circle in the largest group of circles), (D) groups of circles and the row (1st circle in a group of N where N = the number of the row, e.g. 1, 2, 3, 4) and (E) dashes and groups of circles (1st circle after 2 dashes and 2 circles consecutively). The subjects confirmed the difficulty of these principles and the modified ten-symbol format.

A second preliminary test was written, composed of twenty-four items with eight symbols per row. The principles upon which these items were based were modified from the previous test. This list of principles is in Table 2. This form of the CR test was given to several more graduate students, who felt the test was approximately appropriate to a fifthgrade level. A final decision was made to reduce the number of symbols per row to seven. Seven symbols per row facilitated the use of machine-scoring. Although the method of scoring was not a primary factor in the format decision, it was, nonetheless, important enough to be considered since it might affect the usability of the test in the future. In addition, some of the principles were dropped because of complexity or because of dependence upon eight symbols per row. It was concluded that seven symbols was the minimum number possible to allow for variety within the exemplars and in order to include several different kinds of rules in the test.

The decision was made to retain Guilford's format of four exemplars. During the preliminary work the use of three rather than four exemplars was considered. The complexity of the rules and the age of the subjects,

TABLE 2

Principles: Preliminary Circle Reasoning Test
(8 symbols per row)

-
- I. Relative to other circles only
 - A. Ordinal position in a row - stationary
 - 1st circle in a row
 - 2nd circle in a row
 - 3rd circle in a row
 - 4th circle in a row
 - 5th circle in a row
 - 6th circle in a row
 - 7th circle in a row
 - B. Middle circle in row with number of circles in each row varied
 - II. Relative to circles and dashes
 - 1st circle after 1 dash
 - 2nd circle after 1 dash
 - 3rd circle after 1 dash
 - 4th circle after 1 dash
 - 1st circle after 2 dashes
 - 2nd circle after 2 dashes
 - Circle separated from other circles by dashes ("alone")
 - III. Relative to groups of circles (groups defined by dashes)
 - Middle circle in group of 3
 - Middle circle in group of 5
 - Middle circle in group of 7
 - IV. Relative to circles and rows
 - 1st, 2nd, 3rd, 4th, 5th
 - 2, 3, 4, 5, 6
 - 3, 4, 5, 6, 7
 - 4, 5, 6, 7, 8
 - V. Relative to circles, dashes and rows
 - 1st, 2nd, 3rd, 4th, 5th circle after 1 dash
-

however, seemed to support Guilford's format. It was felt that four exemplars would provide the subject with one more row against which to check his hypothesis before marking the test row, and that this fourth exemplar would allow for more difficult rules to be tested.

According to M. L. Harris (1968), it is wise to construct about twice as many items for the field test as will eventually be used since it is difficult to predict exactly what will comprise a good item. Thirty items were constructed for CR-A with a final form length of 15-20 items in mind. Each item consisted of 5 rows of seven symbols each. (See Table 3 for a list of principles.)

The construction of CR-A items entailed a close consideration of rule complexity. For example, one might expect that an item in which the dark circle is related only to other circles in terms of its ordinal position (e.g. 5th circle from left) might be easier than an item in which the dark circle is related to circles and dashes (e.g. 2nd circle after the second dash). A rule in which the ordinal position (1st circle, second, third . . .) of the dark circle changes with each successive row was used in this study even though Guilford's CR test did not include it. This particular rule is similar in nature to Guilford's rule in which the dark circle is related to a group of circles, the size of which varies with the row.

The ambiguity or explicitness of the exemplars was also expected to be an important factor in the difficulty of an item. For instance, in one row two or more rules might be applicable. If three of the four exemplars are similarly ambiguous, the task is more difficult. An attempt was made to construct items that would cover a range of difficulty in regard to this aspect.

TABLE 3

Principles: Circle Reasoning, Forms A and B

		Item Numbers	
		Form A	Form B
I. Relative to other circles only			
A. Ordinal position in a row - (stationary)			
1st circle in a row	3, (Ex.)		
2nd circle in a row	1, 14	1, 16	
3rd circle in a row	11, 24	13, 18	
4th circle in a row	9, 30	3, 9	
5th circle in a row	17, 28	20, 21	
6th circle in a row	13	6	
B. Middle circle in entire row with number of circle in each row varied	10	12	
II. Relative to circles and dashes			
1st circle after 1 dash	25	8	
2nd circle after 1 dash	21		
3rd circle after 1 dash	4, 6	10	
1st circle after 2 consecutive dashes	29	17	
1st circle after 2 dashes (not necessarily consecutive)	23	24	
2nd circle after 2 dashes (not necessarily consecutive)	27	19	
2nd circle after 2 consecutive dashes	12		
Circle separated from other circles by dashes ("alone")	15, 19, (Ex.)	4, 11	
III. Relative to groups of circles (groups defined by dashes)			
1st circle in a group of 2 circles	8, 22	5, 14	
2nd circle in a group of 2 circles	16, 26	7, 22	
middle (second) circle in a group of 3 circles	7, 18	2	
IV. Relative to circles and rows ("sequential order")			
1st, 2nd, 3rd, 4th, 5th	5	23	
2, 3, 4, 5, 6	2	15	
3, 4, 5, 6, 7	20	25	

The next step in the development of CR-A was to consult with two teachers in regard to the appropriateness of the 30-item test for fifth grade. Then the items were informally given to three fifth graders to get a rough estimate of the item difficulties and the time necessary to work the problems. The test took about twenty minutes working time, and the items appeared appropriate for fifth grade subjects.

Finally, the items were assigned to positions on the test, with the first problem being an easy one. Two more elementary problems were written to serve as part of the directions. Since the list of rules for the test included two general types of concepts, ordinal position in relation to other circles, and position relative to dashes or row, one example of each type was used, and specific reference was made to the fact that there were many different types of rules used in the tests. (See Appendices A and B for tests and directions.)

The descriptive statistics for CR-A were quite good for a first field test. The mean was 14.5, nearly half the total possible. The standard deviation was 8.38; the distribution of obtained scores was somewhat flat, which was an acceptable outcome. The standard error (Se) was small (2.17), and the Hoyt ANOVA reliability was quite high (.93).

The GITAP analysis of CR-A showed all items except #10 to have appropriate difficulty levels and biserial correlations. The X_{50} values ranged from $-.87$ to $+1.17$, which were quite acceptable. (Item #10, an exception, will be discussed later.) The betas were generally quite good, from $+0.56$ to $+2.79$, except for item #10. Quite a few

items had incorrect choice betas that were low negative or slightly positive. Because of the large number of possible answers (seven), however, one or two slightly poor betas were not necessarily cause for omission from the revision. Decisions to drop particular items were primarily based on the betas, X_{50} values and rules in such a way that items with a few poor betas were retained if the X_{50} level and rule were valuable. For example, two alternatives in item #27 had low positive betas, but the beta for the correct choice was good ($\beta = +.83$). The rule was: second circle after two dashes, not necessarily adjacent. The rule would seem to be rather difficult, and indeed the X_{50} level was $+.38$. Since it was desirable to include a variety of rules and difficulty levels, this item was included in Form B of Circle Reasoning. Item #21 also had a couple of low betas ($+.07, -.11$). Despite the fact that it was slightly difficult ($X_{50} = +.27$), the item was dropped because two other items (#6, #25) that discriminated better had similar rules. Item #3, 4, and 12 were omitted for the same reasons. Item #20 had several low betas, but it discriminated fairly well ($\beta = +.74$) at a difficult X_{50} level ($+1.17$). The item was based on the "sequential order" rule in which the dark circle is related to both circles and rows. This particular rule is interesting so the item was retained for the revised form. Item #2, also based on the "sequential order" rule was changed slightly for the next field test.

The X_{50} value for item #10 was wild ($+14.31$) as its β was near zero ($.08$). The rule for item #10 was "middle circle in the row, with the number of circles in each row varying from 3 to 7." Apparently

this rule, at least with the particular exemplars given, was too difficult or ambiguous for the 5th grade subjects.

In general, it would appear that the types of rules upon which the items were based were indeed somewhat hierarchical. The eleven items based on "relations to other circles" were for the most part rather easy. The X_{50} values ranged from $-.87$ to $+.07$, with the exception of item #10, which did not function well at all. The easiest items were those in which the dark circle was second or sixth. It would seem that both of these rules would be more readily apparent than rules in which the dark circle is 3rd, 4th, or 5th in a series of 7 symbols.

The next easiest group of items included those rules in which the dark circle is related to groups of circles (e.g. 1st circle in a group of 2 circles). The range of X_{50} values was from $-.20$ to $+.13$. It would seem probable that groups of 2 circles stand out in a series of seven symbols, hence they are more easily detected.

The next difficult items were the ten based on the rules in which the dark circle is related to both circles and dashes (e.g. 2nd circle after two dashes). In this type of rule the S must assimilate both ordinal position of the circles and position relative to the dashes. The range of X_{50} values was $-.46$ to $+.63$. The two easiest items in this group were both based on the principle "alone", or separated from other circles by dashes. One of the examples was based on this rule, which may account for the results. In addition, particularly after having been alerted to the rule, the circle that is "alone" does seem to stand out in the series.

Undoubtedly the most difficult items were the three based on "sequential order" (e.g. the dark circle in Row 1 is the 1st circle in the row; in Row 2 it is the 2nd circle, etc.). The X_{50} values for these items were: +.87, +1.11, +1.17. No example of this type of principle was given so the difficulty may have occurred as a result of some subjects' inability to generalize very far beyond the specific examples given. The betas for these items were satisfactory but not especially high (.56, .74 and .85). Perhaps the ability to solve these problems is more a function of some cognitive style variable than the ability demonstrated by solving most of the other problems in the test.

The X_{50} values of the CR-A items were taken into account in the ordering of the CR-B problems. In general, the more difficult items such as those based on sequential order were placed toward the second half of the test.

Changes were also made in the directions for the second field test. Two important things were learned from the examiners' reports: the blackboard discussion of the examples was essential, and the directions were still not clear enough for the slowest subjects. The directions were rewritten for CR-B to more carefully explain the task and to define "rule". For example, in CR-A, the "rule" is never really defined except by indirect reference. "The first circle in each row is filled in. Following this rule, mark an X on the first circle in the last row." In CR-B "rule" is referred to more explicitly in the first paragraph, and the first example reads: "In each row the dark circle is always the very first circle on the left. This is called the "rule". Following

this rule, which circle in the bottom row would be the dark one?"

In addition, the layout of the directions was improved. In CR-A both examples were explained on one page. This brevity caused a lot of questions, thus creating the possibility of a less standardized administration of the test. Each example in CR-B occupied a single page. This change provided a more complete set of directions, thus eliminating many of the questions raised during the first field test. The problem of explaining the marking of the digitek answer boxes was more carefully explained in CR-B by the simple change of placing the sample row of answer boxes after the sample test row rather than next to the example itself. This format more closely follows the actual steps involved in solving and marking the problems. Arrows pointing to the rows in the examples were added in order to avoid the confusion of rows with columns, as reported by examiners after CR-A. Since it was noted during the testing that several subjects marked the answers boxes for blank spaces rather than circles, a warning was added at the top of each page of CR-B: "Remember, only a circle can be the correct answer. A dash can never be."

The GITAP analysis of CR-B revealed a satisfactory test. The mean was 12.16, with the possible score of 25. The s was 6.84, again indicating a rather flat distribution. The Hoyt reliability was .91, and Se was still small (2.00). (See Table 4 for X_{50} values and βs .)

Most of the twenty-five items functioned well. All item difficulty levels were appropriate, with $.22 \leq p \leq .72$. All but one (item #23) of the X_{50} values obtained were between +1.75 and -.96.

TABLE 4

GITAP Summary: Circle Reasoning, Form B

Rule	Item Number	X ₅₀	β
2nd circle	1	- .07	+1.30
2nd circle	16	- .25	+1.41
3rd circle	13	+ .04	+1.65
3rd circle	18	+ .10	+1.25
4th circle	3	+ .11	+ .93
4th circle	9	+ .14	+ .94
5th circle	20	+ .24	+1.30
5th circle	21	+ .71	+ .64
6th circle	6	- .20	+1.19
Middle circle in row	12	- .25	+2.01
1st circle > 1 dash	8	- .32	+1.47
3rd circle > 1 dash	10	- .24	+ .99
1st circle > 2 consecutive dashes	17	- .60	+ .98
1st circle > 2 dashes	24	+ .13	+ .70
2nd circle > 2 dashes	19	+ .22	+1.23
"alone"	4	- .61	+ .98
"alone"	11	- .96	+ .78
1st circle in group of 2	5	+ .18	+1.52
1st circle in group of 2	14	- .02	+1.43
2nd circle in group of 2	7	+ .14	+ .95
2nd circle in group of 2	22	+ .10	+2.04
Middle circle in group of 3	2	- .24	+1.28
1st, 2nd, 3rd, 4th, 5th	23	+2.63	+ .30
2nd, 3rd, 4th, 5th, 6th	15	+1.60	+ .54
3rd, 4th, 5th, 6th, 7th	25	+1.75	+ .48

Most of the items discriminated well also. Three items, #15, 23 and 25, had r_{bis} lower than .50 however. Their betas were also poor (.54, .30 and .48 respectively), and their X_{50} values were high (+1.60, +2.63, and +1.75). These three items represent the "sequential order" principles. The GITAP information would seem to indicate that these rules were too difficult for the sample. The sample used with CR-B did not appear to be very different from the CR-A sample although no measures of intelligence were available. Lack of such evidence in either direction forces one to carefully examine and compare the two tests as given.

The X_{50} values for items #15, 23 and 25 were lower in CR-A than in CR-B. Compare: 1.11-1.60, .87-2.63, 1.17-1.75. This change in difficulty may have been caused by the change in placement of the items in the test. Item #2 in CR-A was #15 in CR-B, #5 in CR-A was #23 in CR-B, and #20 in CR-A was #25 in CR-B. In the attempt to arrange the CR-B items roughly according to difficulty level a learning set may have been inadvertently introduced. A subject completes nearly half the CR-B test before he encounters an item based on sequential order. Such a situation might indeed hinder recognition of a different type of rule.

The five items based on the rules in which the dark circle is related to groups of circles were of medium difficulty in CR-B, as in CR-A. In Form A their X_{50} values ranged from -.20 to +.13. In Form B, the X_{50} range was -.24 to +.18.

The seven items in CR-B based on rules in which the dark circle is related to both circles and dashes were easier than those in CR-A. This group of items in CR-A ranged from -.46 to +.63 X_{50} values; in CR-B, the

range was $-.96$ to $+.22$. Even the two items based on the "alone" rule, which was also used as an example in the directions, were slightly easier in CR-B than in CR-A.

The ten items of CR-B that were based on rules concerning only other circles were harder than comparable items in CR-A. The CR-B range of X_{50} values was $-.25$ to $+.71$; the range for CR-A was $-.87$ to $+.07$.

The exchange in difficulty level from CR-A to CR-B for the above mentioned groups of items may have been a function of placement, as was hypothesized for the "sequential order" items. In arranging the CR-B items, the easier items according to CR-A were put toward the beginning. The novelty of the task, however, might make any of the first few items difficult. As the subject encounters more and more items he becomes acquainted with the task, and the items are not quite so difficult. Such a situation would account for the slight changes in difficulty.

Differences in achievement between the CR-A and CR-B samples may, of course, be a function of any number of unmeasured variables, such as cognitive style. Until investigations of such variables are conducted, little more can be said to explain the results.

The addition at the top of each page of the warning that dashes could never be correct answers seemed to have had very little effect on CR-B results. As many as 12 subjects still chose a dash for the correct answer on occasion, which is the same proportion as in CR-A. The corresponding betas were somewhat more negative in CR-B. Since betas were negative, these subjects must have had a generally poor grasp of the task involved as evidenced by their tendency to low criterion scores. Undoubtedly a few subjects answered randomly.

From the examiners' reports it would seem that the CR-B directions were clearer and more complete than those of Form A. Twenty items and the directions from Circle Reasoning - Form B were accepted as suitable for the purposes of this study.

Twenty items were chosen for use in factor analytic studies on the basis of betas, X_{50} value and rule. For this purpose items #15, 23 and 25 were omitted. Item #4 was also omitted because it is similar to an example and another problem. It was rather easy, with $X_{50} = -.61$, which was already represented by item #17. Item #16 was omitted because its rule is represented by #1, which was not as easy as #16.

In order to estimate the reliability of the 20 items selected from CR-B, the Spearman-Brown formula was used with the obtained reliability of .91 to correct for shortening the test. Use of this formula assumes that the items omitted are comparable to the retained items. Since the poorest items are usually omitted, this formula may slightly underestimate the reliability, which is desirable. The Spearman-Brown formula is:

$$r_{tt_n} = \frac{nr_{tt}}{1 + (n - 1)r_{tt}}$$

The corrected reliability (r_{tt_n}) is .89, ($r_{tt} = .91, n = 2/3$). It should be noted that merely running the twenty selected items through the GITAP program again would not provide a good estimate of the reliability of the shortened test. Such a procedure would assume that the twenty selected items would correlate with the shorter test in the same way that they correlate with the longer test. Since time limits, ordering effects

and other variables may influence the correlation between each item and the criterion, such an assumption is invalid.

Items #15, 23 and 25 would not be omitted from future revisions of CR-B when the purpose is one of investigation of principles. The author is suspicious of the poor performance of these three items in CR-B as opposed to CR-A. It would seem advisable to include more items of this nature in a third form of the CR test in which the items are scattered throughout the test.

Chapter V

NUMBER SERIES:

DEVELOPMENT AND EVALUATION

A "number series" is a sequence of numbers related by a given rule. The rules may be quite simple, as in the addition of a constant (e.g. for the series: 2 4 6 8, the rule is $+ 2 + 2 + 2$), or the rules may be rather complex, such as those in which several operations are combined (e.g. for the series 10 11 9 27 28 26 78, the rule is $+ 1 - 2 \cdot 3 + 1 - 2 \cdot 3$).

The item format may also vary. One or more numbers may be missing from the sequence, and the task may be free answer or multiple choice fill-in-the-blank(s). In another type of format, there may be an incorrect number included in the series. The wrong number may be extra, or it may take the place of a number that should be included. These series, too, may be free answer or multiple choice.

The first NS test constructed for this study consisted of items in which there were five numbers in a sequence, one of which was a "mistake." The task was to discover the rule that fit the series as a whole and to find the number that should be corrected. This particular task was selected for study because it had not been used in any of the elementary age level batteries discussed in Chapter II. Guilford (1960) used an NS-correction test, as did Slater Cantela (1962).

Thirty items employing integers and fractions were written. The rules included addition, subtraction, multiplication and division of constants (e.g. $+ 2 + 2 + 2$) and of successive amounts (e.g. $+ 1 + 2 + 3 + 4$). These rules were not as easy as those in the PMA Number Facility subtest nor as difficult or diverse as the Lorge-Thorndike or TEA batteries.

After discussion of the items with two teachers, the format was changed slightly. Five numbers per series had been used in order to facilitate the use of machine scoring, (answer sheets with five lettered boxes were available), but it was decided that the task was extremely difficult for fifth grade when only four correct numbers were given. Consequently, each series was lengthened to six numbers. In order to retain the advantages of machine scoring, the first number in each series was not indicated as a possible answer. One new type of rule was included: alternating addition and subtraction (such as $+ 2 - 1 + 2 - 1$). A total of thirty-five items finally comprised NS-A since a 20 item test was desired for the final form. Table 5 lists the rules used. Note that only simple addition and subtraction were used with fractions. In general, simple numbers were employed as much as possible in order to avoid problems of "arithmetic" and to emphasize the task of perceiving the rule.

After all items were critiqued by several former teachers, the position of the correct answer was varied, and two simple items were placed first. The directions emphasized that there were many different

TABLE 5

Principles: Number Series, Forms A and B

		Form A	Form B
		Item Number (Rule)	Item Number (Rule)
I. Operations with Constants			
A. Addition		1(+3), 4(+9), 12(+4), 28(+2), 16(+2/5), 20(+1/3), 26(+1/2), 25(+7)	1(+20), 4(+111), 6(+11), 10(+30), 11(+6), 24(+9), 15(+11)
B. Subtraction		2(-2), 6(-10), 9(-1/2), 21(-6), 23(-3/4), 25(-12), 30(-9), 34(-3)	2(-2), 7(-100)
C. Multiplication		5(•2), 31(•3), 33(•4)	
D. Division		10(÷2), 14(÷3), 17(÷5)	
II. Combinations of Operations			
A. Addition-Subtraction		3(+2-1), 8(+2-5), 32(-2+3)	13(+2-1), 30(+41-139)
B. Addition-Multiplication			18(•3+3), 28(•2+1)
III. Operations with Sequential Numbers			
A. Sequential Addition		19, 24(+1+2+3+4+5) 22(+2+3+4+5+6) 7(+8+9+10+11+12)	3(+7+70+700), 9(+11+111+1111) 12(+10+100+1000), 21(+3600+360+36)
B. Sequential Subtraction		13(-7-6-5-4-3) 15(-6-5-4-3-2) 27(-5-4-3-2-1) 29(•2•3•4•5•6) 18(÷5÷4÷3÷2÷1)	17(-5000-500-50) 16(-5-4-3)
C. Sequential Multiplication			
D. Sequential Division			

TABLE 5 (Continued)

	Form A Item Number (Rule)	Form B Item Number (Rule)
IV. Patterns		
A. Addition		
		5(+0+1+0+1), 8(+1+2+1+2)
		19(+4+3+3+4+3+2)
		26(+0+2+;+0+2+1)
		22(+2+3+4+2+3+4)
		29(+0+1+0+2+0+3)
		14(-15+16-16+17)
		27(+2-3+3-4)
B. Addition-Subtraction		

kinds of patterns in the series, but only one example was given. (See Appendices A and B for directions and tests.)

The GITAP analysis results proved quite interesting though disappointing. The items were rather poor as a whole. With thirty-five possible, the mean was quite low (12.00). The range was 2-31, but it could best be described as 2-23 with one S scoring 31; hence, it was not very skewed. The test was quite difficult for most Ss. The standard deviation was 4.69. The standard error was somewhat high (2.46), and the Hoyt reliability was only .72.

Most of the items discriminated rather poorly. Only nine items had betas greater than .60 and r_{bis} greater than .50, and these items were somewhat difficult, as shown in the table below with the corresponding rules, betas, and biserial correlations:

TABLE 6
Selected NS-B Items

Item number	Rule	X_{50}	β	r_{bis}
35	+7	+ .04	+.83	+.64
26	+ $\frac{1}{2}$	+ .30	+.73	+.59
20	+1/3	+1.00	+.65	+.54
25	-12	+1.03	+.78	+.61
33	.4	+1.25	+.72	+.58
24	+1+2+3+4+5	+1.05	+.80	+.63
19	+1+2+3+4+5	+1.33	+.62	+.51
15	-6-5-4-3-2	+1.11	+.60	+.51
27	-5-4-3-2-1	+1.80	+.72	+.58

It is interesting to note that the items based on simpler rules (e.g. + 3 + 3 + 3 + 3 + 3; - 10 - 10 - 10 - 10 - 10) did not discriminate

clearly at all ($\beta = .37$, $\beta = .47$ respectively). There were few highly negative betas for incorrect choices in the test including the seven items mentioned above. For example, item #2 had the rule "+2," which was similar to the example in the directions. It was quite "easy" in that 93% of the subjects chose the right answer, but its beta was only +.29. The betas for the incorrect choices were not very highly negative: -.15, -.29, -.26, 0.0. The results of NS-A would suggest that the Ss had very little conception of or skill at the task. It appeared that choosing the incorrect number in a series was a much harder task than merely recognizing a given series and adding the next number. In fact, one might argue that the latter task would be a necessary skill prior to successful performance on a test like NS-A.

The field tests confirmed the necessity of both spoken and written directions with an example worked on the board. It was difficult enough for the subjects to grasp the idea of a sequence.

With the assumption that the idea of a number series test in general was not beyond the abilities of fifth graders, the decision was made to change the format of the items while retaining some of the principles of NS-A. It was felt that a six number format limited the types of principles that could be included and restricted the clarity with which those principles could be shown when one number was a "mistake." Therefore, a fill-in-the-blank format was used which was similar to tests used by Thurstone (1938, 1958, 1969), Canisia (1962) and the Lorge-Thorndike Non-verbal Battery (1964). The necessity of

machine scoring dictated the use of multiple choice items.

A list of principles was compiled from NS-A and the Lorge-Thorndike Battery, since the latter test has been more successful in using a number series test with fifth grade subjects. (See Table 5 for a complete list of principles for NS-B.) Rules retained from NS-A were:

- Addition of constant (e.g., +9)
- Subtraction of constant (-20)
- Combination of addition and subtraction (+2-5+2-5)
- Sequential addition (+10+100+1000)
- Sequential subtraction (-5-4-3)

In using these rules in NS-B, fractions and difficult numbers were eliminated. More emphasis was placed on the pattern of numbers rather than their manipulation. For example, addition of constants in NS-A was demonstrated by $+ 7 + 7 + 7$. In NS-B, this rule was applied with simpler numbers . . . e.g. $+ 20 + 20 + 20$.

Two new rules, suggested by the Lorge-Thorndike Battery (1964), were included in place of multiplication and division with constants and with sequential amounts:

- Combination of addition and multiplication ($\cdot 2 + 1 \cdot 2 + 1$)
- Addition in patterns ($0 + 1 + 0 + 2 + 0 + 3 + 0$)

Thirty items were written, each with three to eight numbers in the series, depending on the complexity of the rule. The task was to discover the rule and choose the number that should come next in the sequence from five alternatives.

After the items were written, they were critiqued by two teachers and then revised. The revisions consisted merely of changing a few of the foils. Unlike NS-A, the items for NS-B were arranged in order of

hypothesized difficulty, using the Lorge-Thorndike test as a guide. The positions of the correct answers, of course, were varied. Since the NS-A directions proved somewhat satisfactory, they were retained for NS-B, with one change: two examples were given for NS-B, each showing a different type of rule in order to emphasize range of principles the subjects would encounter.

The GITAP results for NS-B indicated that it was a better test than NS-A in terms of discrimination and reliability. The mean was 18.7 out of 30, which was acceptable although somewhat high. The distribution was slightly negatively skewed. The range was 4-29 with a standard deviation of 5.29. The Hoyt reliability was .84, which was considerably better than the .72 of NS-A. The S_e was also smaller (2.1). It would be advisable to revise NS-B in order to obtain a higher reliability (in the .90s) if the test were to be used for diagnostic purposes. The reliability corrected for 20 selected items by the Spearman-Brown formula was .78.

The NS-B items, on the whole, functioned much better than the first form of the test. The GITAP analysis indicated that six items functioned poorly (#8, 13, 18, 22, 28, and 29). These items had low betas for the correct choice and low negative or sometimes low positive betas for the incorrect choices. For example, in #8, 86 subjects chose the correct answer, but a beta of +.12 indicates that these subjects tended to have lower criterion scores than would be desirable. Choice C discriminated well ($\beta = -.40$), and choice E functioned passably ($\beta = -.11$).

No one chose D at all. Forty-three subjects chose B, but the beta was only $-.06$. This alternative did not discriminate at all.

Most of the NS-B items discriminated rather well; many of the betas were greater than 1.00. The X_{50} values ranged from $+1.32$ to -1.89 without including the six items mentioned above and as very easy item (#5). Most of the items were easy, and only four of them had X_{50} values greater than zero. (See Table 7.)

The easiest items were those based on the addition of constants (e.g. $+20$), the subtraction of constants (e.g. -2) and very simple sequential addition and subtraction (e.g. $+70 +700 +7000$ and $-5000 -500 -5$). These series were simple and required little manipulation of numbers.

The items based on combinations of operations were more difficult (e.g. $+2 - 5$ and $-92 +112$). These patterns were less obvious and consequently they required the subject to be able to "play" with numbers, to manipulate them in order to find the pattern. Two items were based on simple numbers (e.g. $-3 +5$), and two were based on larger numbers (e.g. $+141 -139$). The latter was in fact the easiest item of this group, ($X_{50} = -.34$) perhaps because the answer could also be deduced by the 1st and 3rd numbers in the series alone (e.g. $501 \quad 642 \quad 503 \quad 644 \quad \underline{\quad}$).

The most difficult items were based upon combinations of multiplication and addition (e.g. $*2 +1$) and upon special patterns (e.g. $+0 +1 +0 +2 +0 +3$). Most of the betas for these items were quite poor, which indicates that few if any of the pupils could discover the patterns. In several cases the alternative closest

TABLE 7
GITAP Summary: Number Series-Form B

Rule	Item Number	X_{50}	β
+20	1	-1.63	+ .87
+11	6	-1.40	+1.18
+11	15	-1.33	+2.18
+111	4	-1.10	+ .63
+6	11	- .56	+1.24
+30	10	- .77	+ .60
+9	24	- .47	+ .81
-2	2	-1.51	+1.66
-100	7	-1.81	+1.03
+2 -1	13	+3.88	+ .17
+2 -5	20	+ .57	+ .88
-3 +5	25	+ .81	+ .73
-92 +112 -92 +112	23	+ .65	+ .77
+141 -139 +141 -139	30	- .34	+ .98
+3 +3	18	+1.40	+ .49
+2 +1	28	+2.16	+ .13
+70 +700 +700	3	-1.89	+1.67
+11 +111 +1111	9	- .95	+ .70
+10 +100 +1000	12	- .80	+1.61
+3600 +360 +36	21	-1.04	+1.13
-5000 -500 -50	17	-1.45	+1.38
-5 -4 -3	16	- .71	+1.10
+0 +1 +0 +1	5	-2.75	+ .94
+1 +2 +1 +2	8	-3.19	+ .12
+0 +1 +0 +2 +0 +3	29	+3.43	+ .33
+4 +3 +2 +4 +3 +2	19	+1.32	+ .52
+2 +3 +4 +2 +3 +4	22	+1.09	+ .37
+0 +2 +1 +0 +2 +1	26	- .37	+ .99
+2 -3 +3 -4	27	- .29	+ .77
-15 +16 -16 +17	14	- .93	+1.95

to the correct answer had a positive beta, suggesting that the students with higher criterion scores could see a trend in the series or could see at least one aspect of the series of relations even if they could not master the entire principle. The results also suggested that the higher scoring subjects tended to take their cues from the first and last relations in the most difficult series. The lower scoring subjects seem to have answered somewhat more randomly. The most difficult items, which also discriminated poorest, were those based upon patterns of addition and combinations of multiplication and addition.

The NS-B directions were quite satisfactory. The addition of a second example was an important improvement not to be overlooked in the construction of tests based upon a number of different principles to be appropriate for elementary school levels.

✓

Chapter VI

CORRELATION

Two tests, Circle Reasoning-Form B and Number Series-Form B, were successfully developed for fifth grade subjects. Eighty-seven subjects took both CR-B and NS-B. Based on this sample, the CR-B mean was 12.95/25 with a range of 0 to 25 and standard deviation of 7.04. The NS-B mean was 19.05/30 with a range of 6 to 28 and standard deviation of 5.34. The scores for the 87 subjects on each test were correlated, and the coefficient was .51. The reliabilities for CR-B and NS-B based on 87 Ss were .92 and .84 respectively.

Correcting for attenuation provides a coefficient that is indicative of the correlation between the underlying abilities measured by the two instruments rather than between the somewhat "unreliable" obtained scores. The corrected correlation coefficient was .58, using the following formula (Magnussen, 1967):

$$r_{TG} = \frac{r_{tg}}{\sqrt{r_{tt} r_{gg}}}$$

Since NS-B and CR-B both had relatively high reliabilities the corrected coefficient is not greatly higher than the original coefficient.

The correlation of .58 between CR-B and NS-B indicates that the

ability or abilities measured by the two instruments are correlated. Whether or not the underlying abilities are the same is a question for factor analytic techniques. Past research by Thurstone (1938, 1940) and Guilford and his associates in the 1950's has suggested that the two tests do measure the same type of ability in high school and college age subjects. Thurstone's (1938) correlation of .52 obtained with his Figure Classification and Number Series tests with college subjects is quite similar to the coefficient calculated in the present study. Marks (quite similar to CR) and Number Series correlated .31 with high school subjects. No reliabilities were available for correcting the correlation for attenuation. Guilford *et al.* (1956) found a correlation of .23 for CR and NS (description of rules). Corrected for attenuation, this correlation is .32. In 1960 Guilford *et al.* found CR and NS-correction to be correlated .26, which is .45 when corrected for attenuation.

The .58 correlation obtained in this study may be an indication that the abilities measured by NS-B and CR-B are more correlated at the fifth grade level than at the adult level; however, since the adult and fifth grade tests are not entirely comparable, this hypothesis is left for future research.

Chapter VII

DISCUSSION AND CONCLUSION

The questions posed in Chapter II concerning the development of a Circle Reasoning test and a Number Series test that would be appropriate for fifth grade students have been for the most part answered successfully. Most of the items in Form B of the Circle Reasoning Test discriminated well within a wide X_{50} range. Virtually unsped by examiners' reports, the test had a high Hoyt reliability of .91. The GITAP analysis revealed a hierarchy of rules, the easiest being those based on simple relations between circles and dashes. Of medium difficulty were items based on relationships of circles in groups and to other circles. The most difficult items were based on relations between the particular row and the ordinal position of the circles. In Form A of the CR test these items discriminated satisfactorily, but in Form B they did not. A likely explanation is that a learning set was established by placing the three items towards the end of CR-B instead of scattered throughout the test as in CR-A. Since many tests are arranged with the most difficult items at the end, an investigation of this problem would seem advisable. Had CR-B been given first, the conclusion might have been reached that the circle/row relationships were too difficult for fifth grade subjects.

Another question concerning the appropriateness of circle/row relationships is whether an example of this type of principle should be used. If such an example were given, the test would be, in effect, a short teaching session, and the high scorers would probably be those students who can quickly learn how to recognize problems like the examples. Not including an example of each kind of principle forces the students to go beyond a "matching" technique. This task would seem to be desirable.

It was concluded from the administration of the tests that two examples are necessary. Faced with a novel task, most pupils seem almost afraid to interpret the task in a flexible way.

There has been conflicting evidence of the appropriateness of number series tests to the fifth grade level. The first form tested in this study required the subject to find the number in a series of six that was a "mistake." It proved to be too difficult a task for this age level. The second form of the test, based on NS-A and the Lorge-Thorndike battery, was a fairly good measuring instrument. From examiners' reports the test was unspeeded. The reliability was .84, and there was a range of difficulty level from -1.89 to +1.32. Items based on rules using simple addition or subtraction of constants proved fairly easy. Also easy were items in which the "form" or appearance of the numbers possibly served as clues. Series based on simple combinations of addition and subtraction were of medium difficulty. No example of this type of rule was given; hence the pupils had to think beyond the immediate directions.

The most difficult items were those based on patterns of addition and combinations of addition and multiplication. These rules are the most complex; they differ most from the directions, and, therefore, they require a capacity to go beyond the examples, to "play" with or manipulate the numbers in order to make some sense, some "pattern," out of the series. Poor betas for these items suggest that this ability may be beyond the fifth grade level except when applied to very simple series. Future research investigating the most difficult rules of NS-B is necessary before it is finally concluded that such relationships are actually inappropriate for fifth grade. As with Circle Reasoning, it is possible that an example of the most difficult series might eliminate the problem of poor betas. The question remains, however, as to just what ability is to be measured. Again, as with Circle Reasoning, it would seem preferable to give as few examples as possible. The administration of the tests in this study indicated that two examples were necessary.

The correlation between the Circle Reasoning and Number Series tests based on a sample size of 87 was .51. Corrected for attenuation, the coefficient is .58, which supports the view that the two instruments may measure a single ability at the fifth grade level as claimed with high school and adult subjects in some previous factor analytic research (Thurstone, 1940; Guilford, 1967). This possibility remains to be investigated in future factor analytic studies.

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APPENDICES

APPENDIX A

GENERAL INSTRUCTIONS TO THE EXAMINER

It is advisable that an examiner be familiar with the general instructions and that he follow the standard procedures outlined below.

TIME LIMITS

Each test has a time limit which must not be exceeded. If a student finishes a test early, he may go back over the test. If all pupils finish early, the class may proceed with the next test.

CAUTION AGAINST COACHING

It is important that all pupils understand how to answer the questions, but the examiner must never indicate the correct response for any test items other than the sample problems. This is a test, not a learning activity. The examiner is cautioned against coaching, hinting or providing special help for any students.

CHOOSING CORRECT DIRECTIONS

The instructions for administering each test follow.

From this point on, certain parts of these directions are enclosed in boxes and preceded by SAY: These parts are to be read to the pupils.

COLLECTING TESTS

Answer sheets should be separated according to class and test. That is, there should be a separate stack for each test given to each class.

TIME ALLOTMENT

Directions	- 10 min.
Testing time	- <u>20</u> min.
Total	30 min.

MATERIALS REQUIRED

For each pupil --

test booklet
answer sheet
soft lead pencil with eraser

For examiner --

Manual
test booklet and answer sheet for demonstration
extra pencils
stopwatch or clock with second hand

DIRECTIONS FOLLOW

GENERAL DIRECTIONS FOR THE BEGINNING OF THE
1ST TESTING SESSION IN EACH CLASSROOM

Today your class will be participating in a study of 4th and 5th grade abilities, and we would like you to help us find out how well your class can do some exercises we have prepared. You will be taking two tests today. They are probably not very similar to most of your school-work--but most students find them interesting. Some of the problems may seem hard, but others are easy. No one is expected to know all the answers, but you should try to answer all of them the best you can. Do not spend too much time on any one question.

If your pencil breaks, hold it up, and I will give you another.

We will be using machine-scored answer sheets so be sure to follow directions carefully.

BEFORE EACH TEST:

Distribute 1 pencil and 1 answer sheet to each pupil.

Prepare a model of the top part of the answer sheet with the date ^f your assigned code number (by "instructor") on the blackboard.

NAME			DATE	
	Last First M.I.		Month Day Year	
COURSE	Number Series - Form B INSTRUCTOR			

SAY:

When you receive your pencil and answer sheet print your own name, last name first, and then copy the rest of the information from the model I have written on the board. When you have finished, look at the answer sheet. Be sure to notice that the rows of answer boxes are numbered across the page. (Demonstrate)

Circle Reasoning

Form A

SAY:

The booklet we are going to look at now is concerned with how well you can discover patterns in the ways symbols are arranged. There are only 2 symbols in these exercises--circles and dashes. Some of the problems may seem hard, but some of them are easy if you look carefully. No one is expected to get all of the answers right, but try to answer all of them. If you do not know an answer, go on to the next problem! You may come back to it later if you have time. You will have 20 minutes to work on these problems.

If your pencil breaks or will not write, hold it up and I will give you another.

I will pass out the booklets now. When you receive one, do not open it or look inside. We will all start together.

Pass out booklets.

SAY:

Look at the front of the booklet (demonstrate) and read the directions silently to yourselves as I read them aloud.

In each question there are 5 rows of circles and dashes. One circle in each of the first 4 rows is filled in according to a rule. Find the one rule that applies to all the rows. Mark an X on the circle in the last row which should be filled in. Mark the box on the answer sheet that has the same number as the circle you marked. Remember, only a circle can be a correct answer. A dash can never be a correct answer.

Now let's look at some sample problems.

For examiner

I. - ● - 0 0 - 0
 ● 0 - 0 0 0 0
 - - - ● 0 0 -
 - ● - 0 0 - 0
 - - 0 0 0 0 -
 1 2 3 4 5 6 7

SAY:

Look carefully at the first sample. Find out which circle is the dark one in every row. In each row the dark circle is the very first circle on the left. This is called the "rule". Following this rule, which circle in the bottom row should be the dark one?

That's right. You should mark the first circle on the left. Now the last row should look like this.

- - X 0 0 0 -
 1 2 3 4 5 6 7

The number below your X is 3,--so 3 is the number of the correct answer. The 3-box across from the first example has been marked correctly.

Now let's look at a different example.

For examiner

II. ● - - - 0 0 0
 - ● - 0 0 0 -
 0 0 0 0 0 - ●
 - 0 0 - ● - -
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

Look carefully. Can you find out which circle is the dark one in each row? This may look hard at first. It certainly isn't the first circle in every row like the last problem. It also isn't the last circle in the row, is it? If you look closely you will see that the dark circles are separated from all the other circles by dashes. In every row the dark circle is the only circle that is "alone".

Following this rule, which circle in the bottom row should be dark? Put an X on it. That's right. It is the circle above the number 4. Now it should look like this:

0	0	-	X	-	0	0
1	2	3	4	5	6	7

The 4-box for example II has been marked correctly on the front page.

EACH QUESTION IS DIFFERENT! You will have to look at each one carefully because there are many different kinds of rules. Remember, if you do not know an answer, go on to the next problem. It may be easier, and you may look back later if you have time. There are 30 questions. As I said before, no one is expected to answer all of them correctly, but try to answer as many as you can.

Look at the answer sheet. Be sure to notice that the rows of answer boxes are numbered across the page. (Demonstrate)

After I tell you to start you will have 20 minutes. If you finish early, check your answers, be sure your answer sheet is neatly and correctly marked, and then sit quietly until time is called. If you are ready (pause), turn the page and let's see how well you can do.

Circulate among the students to be sure they mark the answer sheet properly.

If a pupil does not understand the task, he should be directed to read the directions and examples carefully, and then to try his best.

If pupils ask if the test "counts", tell them: "We want to know how well your class can do, so try to do your best."

After 20 minutes --

SAY:

Time is up. Check to be sure your name is on your answer sheet and then pass them forward.

Collect

Now pass your booklets forward.

Collect

If a second test follows, begin. If not, collect pencils, and then thank teacher and class.

DIRECTIONS FOR ADMINISTRATION

Number Series

SAY:

The booklet I am going to hand out now is about numbers and how they may be written to form patterns. Perhaps you have worked with numbers before in this way. Some of the questions may seem hard, but others are easy. No one is expected to know all the answers, but you should try to answer all of them. If you do not know an answer, go on to the next problem. You may come back to it later if you have time. You will have 20 minutes to work on these exercises.

If your pencil breaks or will not write, hold it up, and I will give you another.

Now I will distribute the exercise booklets. When you receive one, do not open it yet or look inside. We will all start working together.

Pass out booklets.

SAY:

Look at the front of the booklet and read the first paragraph labeled "Directions" silently as I read it aloud.

In each question there are six numbers arranged in a certain order. Five of the numbers form a pattern. The other number is a "mistake". You must look at all six numbers and try to find a pattern that fits five of the numbers but not the other one.

Write on blackboard: (do not erase until after test)

2 4 6 8 10 12

SAY:

Here on the board are six numbers that go together to form a pattern.
 (SAY) 2, 4, 6, 8, 10, 12. You can see that the numbers get larger by 2
 each time. This is the pattern that the numbers form: (Write--+2)
 Now look at these six numbers. (SAY) 2, 4, 7, 8, 10, 12.

Write on board below other set: (do not erase)

2	4	7	8	10	12
(A)	(B)	(C)	(D)	(E)	

SAY:

Now there is a "mistake" in the pattern. This is the same as the
 example on the front page of your booklet. Can you find the mistake?
 It is the 7. If the 7 were changed to a 6, the pattern would be correct.
 The letter for 7 is B, so you would mark the B-box for your answer. It
 has already been marked correctly on the front page by example 1.
 Let's look at another set of numbers with a mistake.

Write on board:

30	25	20	15	10	20
(A)	(B)	(C)	(D)	(E)	

SAY:

Can you find a pattern in this set of numbers? You can see that they
 get smaller by 5 each time -- except for one mistake. Which number is it?
 That's right, it's the last 20, with letter E. If the 20 were a 5 it would
 be correct. If this were a problem on the test you would mark the E-box.

Notice that the first number does not have a letter below it; it can never be a "mistake".

Each question on the test is different. You do not always add 2 or subtract 5. In fact you may need to add, subtract, multiply or divide by any number. Be sure to look at each question carefully to discover the pattern and then find the "mistake". Mark the answer box that has the same letter as the "mistake" you find. Be sure to notice that the answer boxes are numbered across the page. There are 35 questions, and you will have 20 minutes, so do not spend too much time on one problem. Remember, if you do not know an answer, go on to the next one. Be sure to match the number of the question you are working on with the same number for the row of answer boxes.

If you finish early, check your answers and be sure your answer sheet is neatly marked. Then sit quietly until time is called.

If there are no questions (pause), turn the page and you may begin.

Circulate among the pupils to be sure they mark the answer sheets clearly and correctly.

After 20 minutes or if everyone finishes early,

SAY:

Time is up. Check to be certain your name is on your answer sheet. Then pass them forward.

Collect

Now pass your booklets forward.

Collect

If followed by a second test, start second one. If not, collect pencils.

DIRECTIONS FOR ADMINISTRATION

Circle Reasoning - Form B

SAY:

The booklet we are going to look at now is concerned with how well you can discover patterns in the ways symbols are arranged. There are only 2 symbols in these exercises--circles and dashes. Some of the problems may seem hard, but some of them are easy if you look carefully. No one is expected to get all of the answers right, but try to answer all of them. Do not spend too much time on one problem.

When you receive your test booklet, do not open it or look inside.
We will all start together.

Pass out booklets.

SAY:

Look at the front of the booklet (demonstrate) and read the directions silently to yourselves as I read them aloud.

Read directions

SAY:

If you finish early, check your answers, be sure your answer sheet is neatly and correctly marked, and then sit quietly until time is called. If you are ready (pause), turn the page and let's see how well you can do.

Circulate among the students to be sure they mark the answer sheet properly.

If a pupil does not understand the task, he should be directed to read the directions and examples carefully, and then to try his best.

If pupils ask if the test "counts", tell them: "We want to know how well your class can do, so try to do your best."

After 20 minutes -- or if everyone is finished, collect materials.

NUMBER SERIES - FORM B

The booklet we will look at now is about numbers. Perhaps you have worked with numbers before in this same way. When you receive your test booklet do not open it or look inside. We will all start together.

Pass out booklets.

Look at the front of the booklet and read the directions silently as I read them aloud.

Read directions to them and then:

Be sure to notice that the answer boxes are numbered across the page. There are 30 questions, so do not spend too much time on one problem. Remember, if you do not know an answer, go on to the next one. Be sure to match the number of the question you are working on with the same number for the row of answer boxes.

If you finish early, check your answers and be sure your answer sheet is neatly marked. Then sit quietly until time is called.

If there are no questions (pause), turn the page and you may begin.

Circulate among the pupils to be sure they mark the answer sheets clearly and correctly.

After 20 minutes or if everyone finished early, collect materials.

APPENDIX B

CIRCLE REASONING - FORM A

Directions

In each question there are 5 rows of circles and dashes. One circle in each of the first 4 rows is filled in according to a rule. Find the rule that applies to all the rows. Mark an X on the circle in the last row which should be filled in. Mark the box on the answer sheet that has the same number as the circle you marked. Remember, only a circle can be a correct answer. A dash can never be a correct answer.

Here are some sample questions:

I. - ● - 0 0 - 0
 ● 0 - 0 0 0 0
 - - - ● 0 0 -
 - ● - 0 0 - 0
 - - 0 0 0 0 -
 1 2 3 4 5 6 7

I.

1	2	3
4	5	6

Which circles are dark in the first 4 rows? The first circle in each row is filled in. Following this rule, mark an X on the first circle in the last row. The last row should look like this:

- - X 0 0 0 -
 1 2 3 4 5 6 7

The number of the correct answer is 3. The 3-Box above has been marked correctly.

II. ● - - - 0 0 0
 - ● - 0 0 0 -
 0 0 0 0 0 - ●
 - 0 0 - ● - -
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

II.

1	2	3
4	5	6

Which circles are dark in the first 4 rows? The circles that are alone are filled in. Following this rule, mark an X on the circle that is alone in the last row. Now it should look like this:

0 0 - X - 0 0
 1 2 3 4 5 6 7

The number of the correct answer is 4. The 4-Box above has been marked correctly.

EACH QUESTION IS DIFFERENT. Be sure to look at each one carefully. There are many different kinds of rules in this test. There are 30 questions. Answer all of them. You may begin.

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1. 0 ● - - - 0 -
 0 - ● - 0 - -
 - - 0 - - ● 0
 - - - 0 ● 0 -
 0 0 - - - 0 -
 1 2 3 4 5 6 7

2. 0 - ● 0 0 0 -
 0 0 ● - - 0 -
 - - 0 0 0 ● 0
 - 0 0 0 0 - ●
 0 0 0 - 0 0 0
 1 2 3 4 5 6 7

3. ● - - 0 - 0 0
 - - ● 0 0 - 0
 - ● - - 0 0 0
 ● - 0 0 0 0 -
 - 0 0 - 0 - 0
 1 2 3 4 5 6 7

4. 0 0 - 0 0 ● 0
 0 0 0 - 0 0 ●
 - 0 0 ● 0 0 -
 0 - 0 0 ● - -
 - 0 0 0 - 0 0
 1 2 3 4 5 6 7

5. ● 0 0 - 0 0 0
 - 0 ● 0 0 - -
 0 0 ● 0 - - 0
 - 0 0 - 0 ● 0
 0 0 0 0 0 - -
 1 2 3 4 5 6 7

6. 0 0 0 - 0 0 ●
 0 - 0 0 ● 0 0
 0 0 - 0 0 ● -
 0 - 0 0 ● - 0
 0 0 - 0 0 0 -
 1 2 3 4 5 6 7

7. 0 ● 0 - - 0 0
 - 0 - 0 ● 0 -
 0 - 0 ● 0 - 0
 0 0 - - 0 ● 0
 - 0 0 0 - - 0
 1 2 3 4 5 6 7

8. 0 - ● 0 - - -
 ● 0 - - 0 0 0
 - - - ● 0 - 0
 - ● 0 - 0 0 0
 0 - 0 - - 0 0
 1 2 3 4 5 6 7

9. 0 0 0 ● - 0 0
 0 0 - 0 ● 0 0
 0 - 0 - 0 - ●
 0 0 - - - 0 ●
 0 0 - 0 0 - 0
 1 2 3 4 5 6 7

10. 0 ● - - 0 - -
 0 0 0 ● 0 0 0
 0 0 ● 0 - - 0
 0 ● 0 - - - -
 0 - 0 - 0 0 0
 1 2 3 4 5 6 7

11. 0 0 ● 0 0 - 0
 - 0 0 ● 0 - -
 0 0 ● - 0 0 0
 - - 0 - 0 ● 0
 - - - 0 0 0 0
 1 2 3 4 5 6 7

12. 0 0 - - 0 ● 0
 - - 0 ● - 0 -
 0 0 0 - - 0 ●
 0 - - 0 ● 0 0
 0 0 - - 0 0 -
 1 2 3 4 5 6 7

13. 0 0 0 - 0 0 ●
 0 0 0 0 0 ● 0
 - 0 0 0 0 0 ●
 0 0 0 0 - 0 ●
 0 0 0 0 0 0 -
 1 2 3 4 5 6 7

14. 0 - ● 0 0 0 -
 0 ● 0 0 - - 0
 0 ● - - 0 0 0
 - - 0 ● 0 - -
 0 - - 0 0 0 0
 1 2 3 4 5 6 7

15. ● - 0 0 0 - -
 0 0 - ● - - -
 0 0 0 - - ● -
 - - ● - - 0 0
 0 0 - - 0 - -
 1 2 3 4 5 6 7

16. 0 - 0 ● - - 0
 0 0 0 - 0 ● -
 - 0 - 0 ● - 0
 0 0 0 0 - 0 ●
 - 0 0 - 0 - 0
 1 2 3 4 5 6 7

17. 0 0 - 0 0 ● -
 - - 0 0 0 0 ●
 0 0 0 0 ● 0 -
 0 - 0 - 0 0 ●
 0 0 0 - 0 0 0
 1 2 3 4 5 6 7

18. - 0 - 0 ● 0 -
 0 ● 0 - - 0 0
 - 0 ● 0 - - -
 - 0 0 - 0 ● 0
 - 0 - 0 0 0 -
 1 2 3 4 5 6 7

19. 0 0 0 - ● - -
 ● - 0 0 0 0 0
 - - ● - - 0 0
 0 0 0 0 - ● -
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

20. 0 - - 0 ● - 0
 0 0 0 ● 0 0 0
 0 0 - 0 0 ● -
 0 0 0 - 0 0 ●
 0 0 0 0 0 0 0
 1 2 3 4 5 6 7

21. 0 0 0 - 0 ● 0
 - 0 ● 0 0 - -
 0 - 0 ● 0 0 0
 0 0 0 0 - 0 ●
 0 0 - 0 0 0 -
 1 2 3 4 5 6 7

22. ● 0 - - 0 0 0
 - - ● 0 - - 0
 0 - 0 - ● 0 -
 0 - ● 0 - - 0
 0 0 0 - 0 0 -
 1 2 3 4 5 6 7

23. 0 0 - - ● 0 0
 - 0 - ● 0 0 0
 0 0 0 0 - - ●
 0 0 0 - 0 - ●
 0 0 - 0 0 - 0
 1 2 3 4 5 6 7

24. - 0 0 ● 0 0 -
 0 0 ● - 0 0 0
 - - - 0 0 - ●
 0 - 0 ● - - 0
 0 - 0 - 0 0 0
 1 2 3 4 5 6 7

25. - ● 0 0 0 0 0
 0 0 - ● 0 0 -
 - ● - - 0 0 0
 0 0 0 0 0 - ●
 0 0 0 - 0 0 0
 1 2 3 4 5 6 7

26. 0 0 0 - 0 ● -
 0 ● - - - 0 -
 0 - 0 ● - - 0
 0 ● - 0 0 0 0
 0 - - 0 0 - 0
 1 2 3 4 5 6 7

27. 0 0 - 0 - 0 ●
 0 - - 0 ● 0 0
 0 0 0 - - 0 ●
 0 - 0 - 0 ● 0
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

28. 0 0 - 0 - 0 ●
 0 0 0 - 0 ● 0
 0 0 0 0 ● 0 0
 0 0 - - 0 0 ●
 0 - 0 0 0 - 0
 1 2 3 4 5 6 7

29. 0 0 - - ● 0 0
 0 - - ● - 0 0
 0 0 0 0 - - ●
 - - ● - 0 - 0
 0 0 - - 0 - -
 1 2 3 4 5 6 7

30. 0 - 0 0 ● 0 -
 0 - - 0 0 ● 0
 0 0 0 - ● - 0
 0 0 0 ● 0 - 0
 0 0 - 0 0 - 0
 1 2 3 4 5 6 7

CIRCLE REASONING - FORM B

Directions:

In each question there are 5 rows of circles and dashes. In each of the first 4 rows one circle is dark. These dark circles show you the "rule" for deciding which circle should be dark in the last row. You are to figure out the rule that fits the first 4 rows. Then use the rule to decide which circle should be dark in the last row. On your test booklet, put an X on the circle that should be dark.

Look at some examples below.

EXAMPLE I. - ● - 0 0 - 0 ← (Row 1)
 ● 0 - 0 0 0 0 ← (Row 2)
 - - - ● 0 0 - ← (Row 3)
 - ● - 0 0 - 0 ← (Row 4)
 - - 0 0 0 0 - ← Which circle should be dark?
 1 2 3 4 5 6 7

Look carefully at the first example. Find out which circle is the dark one in every row. In each row the dark circle is always the very first circle on the left. This is called the "rule". Following this rule, which circle in the bottom row should be the dark one?

That's right. You should mark the first circle on the left. Now the last row should look like this:

- - X 0 0 0 -
 1 2 3 4 5 6 7

The number below your X is 3,--so 3 is the number of the correct answer. Here is a sample row of answer boxes that is marked correctly for this example. The 3-box has been filled in.

I.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

Now turn the page and look at a second example.

Directions (con't.)

EXAMPLE II. ● - - - 0 0 0
 - ● - 0 0 0 -
 0 0 0 0 0 - ●
 - 0 0 - ● - -
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

Look carefully. Can you find out which circle is the dark one in each row? This may look hard at first. The dark circle is not always the first circle in every row like the last problem. It also isn't always the last circle in the row, is it? If you look closely you will see that the dark circles are separated from all the other circles by dashes. In every row the dark circle is the only circle that is "alone". Following this rule, which circle in the bottom row should be dark? Put an X on it. That's right. It is the circle above the number 4. Now it should look like this:

0 0 - X - 0 0
 1 2 3 4 5 6 7

The answer box for example II has been marked correctly here:

II. $\begin{array}{|c|c|c|c|c|c|c|} \hline 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ \hline \end{array}$

EACH QUESTION IS DIFFERENT! You will have to look at each one carefully because there are many different kinds of rules. If you do not know an answer, go on to the next problem. It may be easier, and you may look back later if you have time. There are 25 questions. No one is expected to answer all of them correctly, but try to do all of them.

Do not turn the page until told to do so.

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CIRCLE REASONING - FORM B

Remember, only a circle can be the correct answer. A dash can never be.

1. 0 ● - - - 0 -
 0 - ● - 0 - -
 - - 0 - - ● 0
 - - - 0 ● 0 -
 0 0 - - - 0 -
 1 2 3 4 5 6 7

6. 0 0 0 - 0 0 ●
 0 0 0 0 0 ● 0
 - 0 0 0 0 0 ●
 0 0 0 0 - 0 ●
 0 0 0 0 0 0 -
 1 2 3 4 5 6 7

2. 0 ● 0 - - 0 0
 - 0 - 0 ● 0 -
 0 - 0 ● 0 - 0
 0 0 - - 0 ● 0
 - 0 0 0 - - 0
 1 2 3 4 5 6 7

7. 0 - 0 ● - - 0
 0 0 0 - 0 ● -
 - 0 - 0 ● - 0
 0 0 0 0 - 0 ●
 - 0 0 - 0 - 0
 1 2 3 4 5 6 7

3. 0 0 0 ● - 0 0
 0 0 - 0 ● 0 0
 0 - 0 - 0 - ●
 0 0 - - - 0 ●
 0 0 - 0 0 - 0
 1 2 3 4 5 6 7

8. - ● 0 0 0 0 0
 0 0 - ● 0 0 -
 - ● - - 0 0 0
 0 0 0 0 0 - ●
 0 0 0 - 0 0 0
 1 2 3 4 5 6 7

4. ● - 0 0 0 - -
 0 0 - ● - - -
 0 0 0 - - ● -
 - - ● - - 0 0
 0 0 - - 0 - -
 1 2 3 4 5 6 7

9. 0 - 0 0 ● 0 -
 0 - - 0 0 ● 0
 0 0 0 - ● - 0
 0 0 0 ● 0 - 0
 0 0 - 0 0 - 0
 1 2 3 4 5 6 7

5. 0 - ● 0 - - -
 ● 0 - - 0 0 0
 - - - ● 0 - 0
 - ● 0 - 0 0 0
 0 - 0 - - 0 0
 1 2 3 4 5 6 7

10. 0 0 0 - 0 0 ●
 0 - 0 0 ● 0 0
 0 0 - 0 0 ● -
 0 - 0 0 ● - 0
 0 0 - 0 0 0 -
 1 2 3 4 5 6 7

GO ON TO THE NEXT PAGE.

CIRCLE REASONING - FORM B

Remember, only a circle can be the correct answer. A dash can never be.

11. 0 0 0 - ● - -
 ● - 0 0 0 0 0
 - - ● - - 0 0
 0 0 0 0 - ● -
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

12. - 0 - 0 ● 0 -
 0 ● 0 - - 0 0
 - 0 ● 0 - - -
 - 0 0 - 0 ● 0
 - 0 - 0 0 0 -
 1 2 3 4 5 6 7

13. 0 0 ● 0 0 - 0
 - 0 0 ● 0 - -
 0 0 ● - 0 0 0
 - - 0 - 0 ● 0
 - - - 0 0 0 0
 1 2 3 4 5 6 7

14. ● 0 - - 0 0 0
 - - ● 0 - - 0
 0 - 0 - ● 0 -
 0 - ● 0 - - 0
 0 0 0 - 0 0 -
 1 2 3 4 5 6 7

15. 0 ● - 0 0 0 -
 - 0 0 ● 0 - -
 0 0 0 ● 0 - 0
 - 0 0 0 0 - ●
 0 0 0 - 0 0 0
 1 2 3 4 5 6 7

16. 0 - ● 0 0 0 -
 0 ● 0 0 - - 0
 0 ● - - 0 0 0
 - - 0 ● 0 - -
 0 - - 0 0 0 0
 1 2 3 4 5 6 7

17. 0 0 - - ● 0 0
 0 - - ● - 0 0
 0 0 0 0 - - ●
 - - ● - 0 - 0
 0 0 - - 0 - -
 1 2 3 4 5 6 7

18. - 0 0 ● 0 0 -
 0 0 ● - 0 0 0
 - - - 0 0 - ●
 0 - 0 ● - - 0
 0 - 0 - 0 0 0
 1 2 3 4 5 6 7

19. 0 - 0 0 - 0 ●
 0 - - 0 ● 0 0
 0 0 0 - - 0 ●
 0 - 0 - 0 ● 0
 0 0 - 0 - 0 0
 1 2 3 4 5 6 7

20. 0 0 - 0 0 ● -
 - - 0 0 0 0 ●
 0 0 0 0 ● 0 -
 0 - 0 - 0 0 ●
 0 0 0 - 0 0 0
 1 2 3 4 5 6 7

CIRCLE REASONING - FORM B

Remember, only a circle can be the correct answer. A dash can never be.

21. 0 0 - 0 - 0 ●
 0 0 0 - 0 ● 0
 0 0 0 0 ● 0 0
 0 0 - - 0 0 ●
 0 - 0 0 0 - 0
 1 2 3 4 5 6 7

22. 0 0 0 - 0 ● -
 0 ● - - - 0 -
 0 - 0 ● - - 0
 0 ● - 0 0 0 0
 0 - - 0 0 - 0
 1 2 3 4 5 6 7

23. ● 0 0 - 0 0 0
 - 0 ● 0 0 - -
 0 0 ● 0 - - 0
 - 0 0 - 0 ● 0
 0 0 0 0 0 - -
 1 2 3 4 5 6 7

24. - 0 0 - ● 0 0
 - 0 - ● 0 0 0
 0 0 0 0 - - ●
 0 0 0 - 0 - ●
 0 0 - 0 0 - 0
 1 2 3 4 5 6 7

25. 0 - - 0 ● - 0
 0 0 0 ● 0 0 0
 0 0 - 0 0 ● -
 0 0 0 - 0 0 ●
 0 0 0 0 0 0 0
 1 2 3 4 5 6 7

STOP HERE.

Directions

In each question there are six numbers arranged in a certain order. Five of the numbers form a pattern. The other number is a "mistake." Look at all six numbers and try to find a pattern that fits five of the numbers but not the other one. On the answer sheet, fill in the answer box which has the same letter as the one below the "mistake" (the number which does not belong).

Notice that the first number does not have a letter below it; it cannot be a "mistake."

Here is an example:

I. 2 4 7 8 10 12

I. A ☒ C D E

(A) (B) (C) (D) (E)

Can you find the pattern in the order of numbers?

The numbers get larger by 2 each time if we change the 7 to 6.

Instead of

2	4	7	8	10	12
	+2	+3	+1	+2	+2

we would have

2	4	6	8	10	12
	+2	+2	+2	+2	+2

7 is the "mistake." Its letter is B. The B-box above is marked correctly.

EACH QUESTION IS DIFFERENT. You do not always add 2. Be sure to look at each question carefully to discover the pattern and the mistake.

There are 35 questions. Answer all of them. You may begin.

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NUMBER SERIES---page 1

1. 1 4 7 10 12 16
 (A) (B) (C) (D) (E)
2. 12 10 7 6 4 2
 (A) (B) (C) (D) (E)
3. 1 3 2 4 3 2
 (A) (B) (C) (D) (E)
4. 4 13 22 31 38 49
 (A) (B) (C) (D) (E)
5. 1 2 4 8 16 34
 (A) (B) (C) (D) (E)
6. 74 64 45 44 34 24
 (A) (B) (C) (D) (E)
7. 6 15 23 33 44 56
 (A) (B) (C) (D) (E)

GO ON TO NEXT PAGE

- | | | | | | | |
|-----|-----|----------------|----------------|----------------|-----|----------------|
| 8. | 240 | 48 | 12 | 4 | 2 | 1 |
| | | (A) | (B) | (C) | (D) | (E) |
| 9. | 4 | $3\frac{1}{2}$ | $3\frac{1}{4}$ | $2\frac{1}{2}$ | 2 | $1\frac{1}{2}$ |
| | | (A) | (B) | (C) | (D) | (E) |
| 10. | 96 | 36 | 24 | 12 | 6 | 3 |
| | | (A) | (B) | (C) | (D) | (E) |
| 11. | 20 | 16 | 11 | 8 | 6 | 5 |
| | | (A) | (B) | (C) | (D) | (E) |
| 12. | 5 | 9 | 13 | 17 | 22 | 25 |
| | | (A) | (B) | (C) | (D) | (E) |
| 13. | 25 | 21 | 12 | 7 | 3 | 0 |
| | | (A) | (B) | (C) | (D) | (E) |
| 14. | 243 | 73 | 27 | 9 | 3 | 1 |
| | | (A) | (B) | (C) | (D) | (E) |

NUMBER SERIES---page 3

15. 21 15 10 7 3 1
 (A) (B) (C) (D) (E)
16. $\frac{2}{5}$ $\frac{4}{5}$ 1 $1\frac{3}{5}$ 2 $2\frac{2}{5}$
 (A) (B) (C) (D) (E)
17. 3125 625 125 50 5 1
 (A) (B) (C) (D) (E)
18. 20 22 17 19 15 16
 (A) (B) (C) (D) (E)
19. 10 11 13 16 21 25
 (A) (B) (C) (D) (E)
20. $\frac{2}{3}$ 1 $1\frac{1}{3}$ $1\frac{2}{3}$ 2 $2\frac{2}{3}$
 (A) (B) (C) (D) (E)
21. 32 26 20 14 6 2
 (A) (B) (C) (D) (E)

GO ON TO NEXT PAGE

NUMBER SERIES---page 4

22. 5 7 10 15 19 25
 (A) (B) (C) (D) (E)

23. $3\frac{3}{4}$ 3 $2\frac{1}{4}$ $1\frac{3}{4}$ $\frac{3}{4}$ 0
 (A) (B) (C) (D) (E)

24. 2 3 5 8 12 16
 (A) (B) (C) (D) (E)

25. 73 61 49 37 23 13
 (A) (B) (C) (D) (E)

26. $4\frac{1}{2}$ 5 $5\frac{1}{5}$ 6 $6\frac{1}{2}$ 7
 (A) (B) (C) (D) (E)

27. 19 14 10 7 5 3
 (A) (B) (C) (D) (E)

28. 1 2 5 7 9 11
 (A) (B) (C) (D) (E)

29.	1	2	7	24	120	720
		(A)	(B)	(C)	(D)	(E)

30.	45	37	27	18	9	0
		(A)	(B)	(C)	(D)	(E)

31.	1	3	8	27	81	243
		(A)	(B)	(C)	(D)	(E)

32.	4	2	5	3	7	4
		(A)	(B)	(C)	(D)	(E)

33.	1	4	16	82	256	1024
		(A)	(B)	(C)	(D)	(E)

34.	17	14	11	7	5	2
		(A)	(B)	(C)	(D)	(E)

35.	3	10	17	25	31	38
		(A)	(B)	(C)	(D)	(E)

Directions:

In each question in this test there is a series of numbers given in a certain order. You are to discover the order (or way) in which the series of numbers is arranged and then find the number at the right which should come next.

Look at the first example.

EXAMPLE I. 7 8 9 10 — A. 7
B. 8
C. 10
D. 11
E. 12

In this series of numbers (7, 8, 9, 10) each number is 1 more than the number before it. The next number after 10 should be 11. The letter in front of 11 is (D). The D-box below has been marked correctly.

I. ☒ D

Here is another example. Which number should come next?

EXAMPLE II. 8 8 7 7 6 — A. 4
B. 5
C. 6
D. 7
E. 8

The next number should be 6. Its letter is C, so the C-box below has been marked correctly.

II. ☒ C

Look at each question carefully. There are many different orders of numbers. Choose the best answer for each question.

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NUMBER SERIES - FORM B

Choose the best answer to fill in the blank.

- 1** 20 40 60 80 _____
A. 90
B. 100
C. 110
D. 120
E. 130
- 2** 10 8 6 4 _____
A. 5
B. 4
C. 3
D. 2
E. 1
- 3** 7 77 777 _____
A. 7
B. 77
C. 777
D. 7777
E. 77777
- 4** 123 234 345 _____
A. 346
B. 356
C. 456
D. 465
E. 567
- 5** 4 4 5 5 6 _____
A. 3
B. 4
C. 5
D. 6
E. 7
- 6** 15 26 37 48 _____
A. 12
B. 23
C. 51
D. 59
E. 68

GO TO NEXT PAGE

7

782 682 582 482 _____

- A. 382
- B. 438
- C. 542
- D. 658
- E. 682

8

1 2 4 5 7 _____

- A. 8
- B. 9
- C. 10
- D. 11
- E. 12

9

1 12 123 _____

- A. 12
- B. 123
- C. 1234
- D. 234
- E. 4

10

84 114 144 174 204 _____

- A. 124
- B. 234
- C. 384
- D. 404
- E. 814

11

2 8 14 20 _____

- A. 16
- B. 20
- C. 22
- D. 24
- E. 26

12

3334 3344 3444 _____

- A. 3334
- B. 4434
- C. 4344
- D. 4443
- E. 4444

GO TO NEXT PAGE

NUMBER SERIES - FORM B - Page 3

13

1 3 2 4 3 5 —

- A. 3
- B. 4
- C. 5
- D. 6
- E. 7

14

20 5 21 5 —

- A. 5
- B. 15
- C. 22
- D. 25
- E. 26

15

33 44 55 66 —

- A. 67
- B. 76
- C. 77
- D. 88
- E. 99

16

30 25 21 18 —

- A. 28
- B. 23
- C. 20
- D. 17
- E. 16

17

5555 555 55 —

- A. 5
- B. 55
- C. 555
- D. 5555
- E. 55555

18

7 21 10 30 13 39 —

- A. 16
- B. 19
- C. 48
- D. 92
- E. 108

GO TO NEXT PAGE

NUMBER SERIES - FORM B - Page 4

19

2 6 9 11 15 18 20 _____
A. 22
B. 23
C. 24
D. 25
E. 26

20

20 22 17 19 14 16 11 _____
A. 15
B. 13
C. 12
D. 9
E. 6

21

5999 9599 9959 _____
A. 9999
B. 9959
C. 9995
D. 5559

22

10 12 15 19 21 24 28 _____
A. 29
B. 30
C. 31
D. 32
E. 33

23

917 825 937 845 _____
A. 825
B. 856
C. 938
D. 947
E. 957

24

19 28 37 46 _____
A. 51
B. 52
C. 53
D. 54
E. 55

GO TO NEXT PAGE

4 1 6 3 8 5

- A. 7
B. 9
C. 10
D. 11
E. 12

1 1 3 2 2 4 3 3

- A. 1
B. 2
C. 4
D. 5
E. 6

4 6 3 6

- A. 1
B. 2
C. 3
D. 5
E. 6

3 6 7 14 15 30 _____

- A. 31
B. 32
C. 45
D. 60
E. 67

2 2 3 3 5 5 8 8

- A. 9
B. 10
C. 11
D. 12
E. 13

501 642 503 644 _____

- A. 505
B. 541
C. 604
D. 646
E. 705

STOP HERE